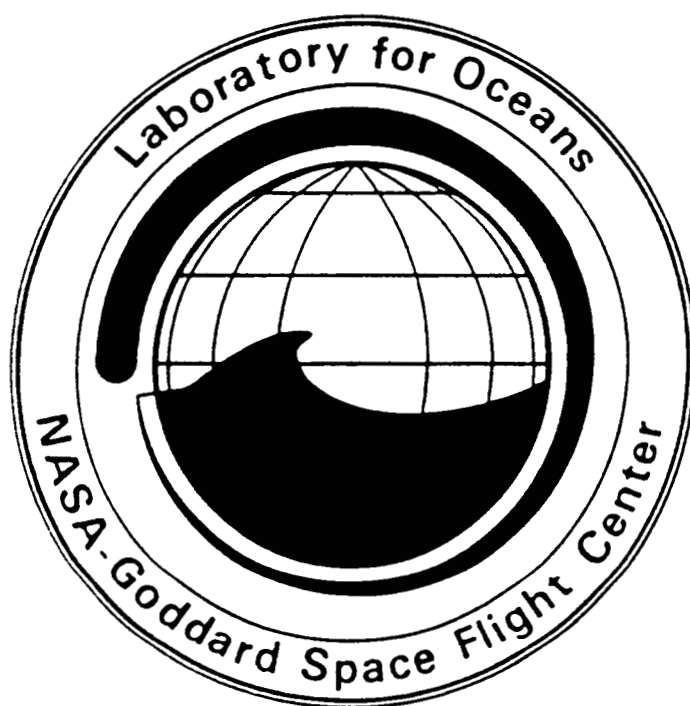


Laboratory for Oceans

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ACTIVITIES REPORT



FEBRUARY 1986 - APRIL 1988

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

LABORATORY FOR OCEANS

ACTIVITIES REPORT

February 1986/April 1988

**Space and Earth Sciences Directorate
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771**

FOREWORD

This report has been prepared in response to the need for an annual overview of the activities of the Laboratory for Oceans; it contains information that is useful to management and to colleagues inside and outside of NASA. The activities of the Laboratory do reflect the capabilities and interests of its staff, as well as the history of the organizational elements that were joined to form the Laboratory. Its professional staff is nearly evenly divided between engineering and scientific personnel, the work in the Laboratory has a corresponding distribution of emphasis. The other Earth science laboratories in the Directorate of Space and Earth Sciences rely on the Laboratory for Oceans for a significant portion of their engineering support in aircraft remote sensing projects and sensor development. The collaboration with the other Earth science divisions also extends into scientific research, since the earth sciences tend to be closely related. Among them, climate dynamics involves atmospheric, terrestrial and oceanic sciences in terms of physics, chemistry and biology.

This report documents how NASA goals are being supported by work in the Laboratory. The introduction gives an overview of laboratory capabilities and activities. Short reports on separate projects follow, with a list of publications and a listing of personnel.

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GENERAL OVERVIEW

The strength and character of the Laboratory lies in its professional staff, which is made up half of engineers and half of scientists. The entire staff contributes to the solution of problems in Earth and planetary sciences, working individually and directly on scientific problems or as members of teams addressing challenges in engineering and science.

The Laboratory represents an important resource for technology within the Earth science divisions at GSFC; one consequence is the Laboratory participates in a wide range of terrestrial and atmospheric science projects through its engineering support to the other Earth science divisions. This deliberate concentration of engineering resources allows better utilization of expertise, and broadens the range of in-house expertise one can justify and maintain. As is apparent from this activities report, the Laboratory contributes engineering design skills to aircraft and ground-based experiments in terrestrial and atmospheric sciences in cooperation with scientists from our sister laboratories in the Earth sciences. Space flight instruments are also being planned, developed and built in the preview of the Laboratory or with significant participation by Laboratory engineers. Examples are the TOPEX altimeter, the Mars Explorer Mission altimeter, the sensor complement for the Tropical Rainfall Measurement Mission as a follow-up to a series of passive microwave sensors that have been flown or are destined or intended for future missions.

Our work in passive microwave radiometry includes a 1.5 Gigahertz radiometer for observing soil moisture, the Electronically Scanned Thinned Array Radiometer (ESTAR), the High Resolution Multi-frequency Microwave Radiometer (HRMMR) and other passive radiometers with a variety of combinations of frequencies and scanning capabilities.

Our work in laser altimetry has brought us near flight mission readiness, aircraft altimetry is a promising field now that the Global Positioning System (GPS) is available. Passive optical sensors are also being worked on along many lines for a variety of research applications. Among the latter are the data system for SeaWiFS, the Ocean Color Sensor destined for Landsat-6, and Moderate Resolution Imaging Spectrometer (MODIS), for the Eos polar orbiter.

The scientists in the Laboratory do all the research that use space technology as a tool of inquiry or satellite data as an important source of data. The scientists are recognized members of their respective research communities, they are all engaged in collaborative efforts with colleagues at universities and laboratories in the United States and abroad. The expanded use of satellite sensors as a research data source can best be promoted through examples of use, efforts at making the data more easily accessible and through the development of new methods of data interpretation. The modern approach to data analysis is through computers, and the combination of numerical modeling of oceanic

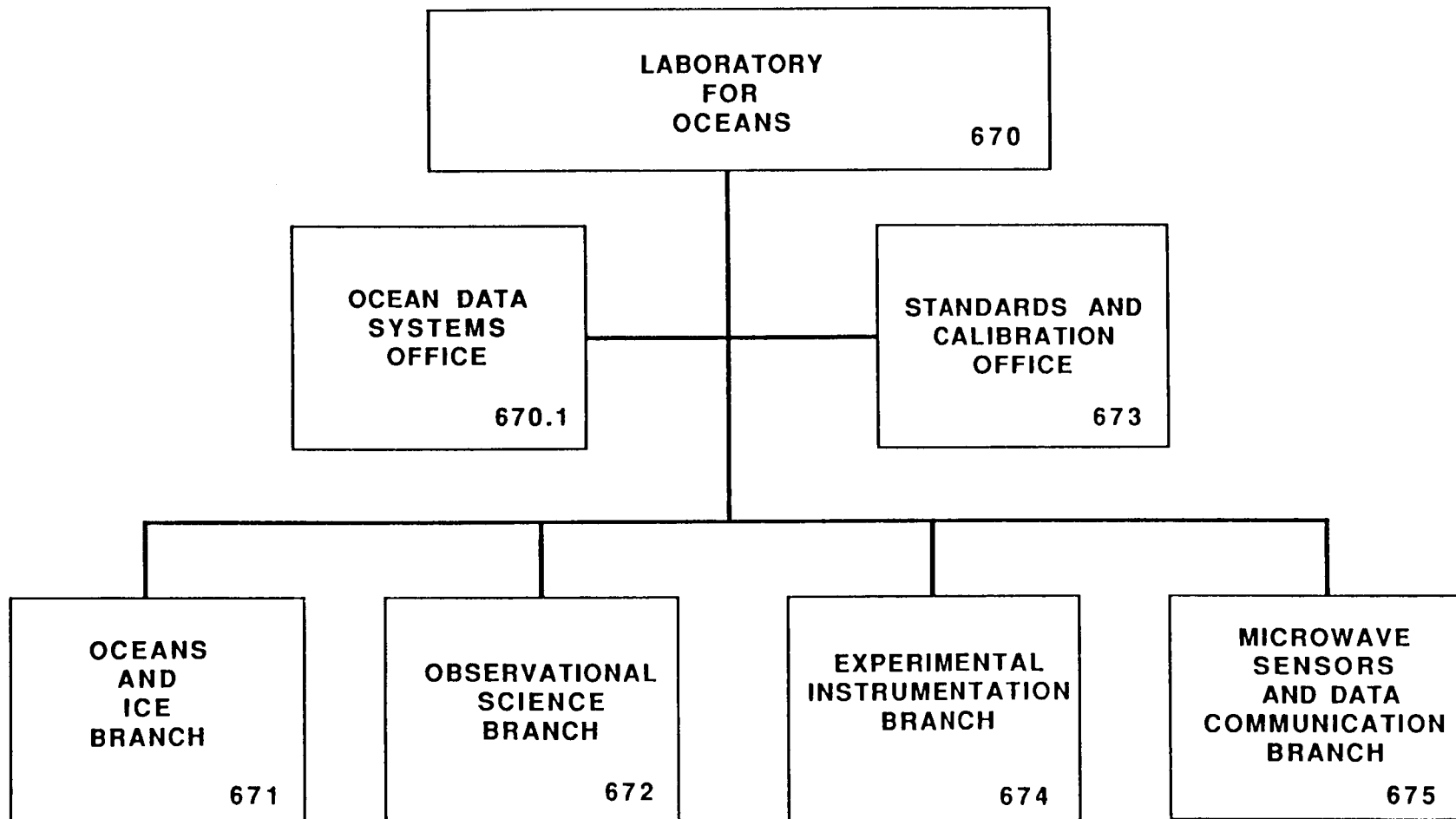
processes and data processing is now under intensive development. Scientists from the Laboratory participate in all aspect of this work.

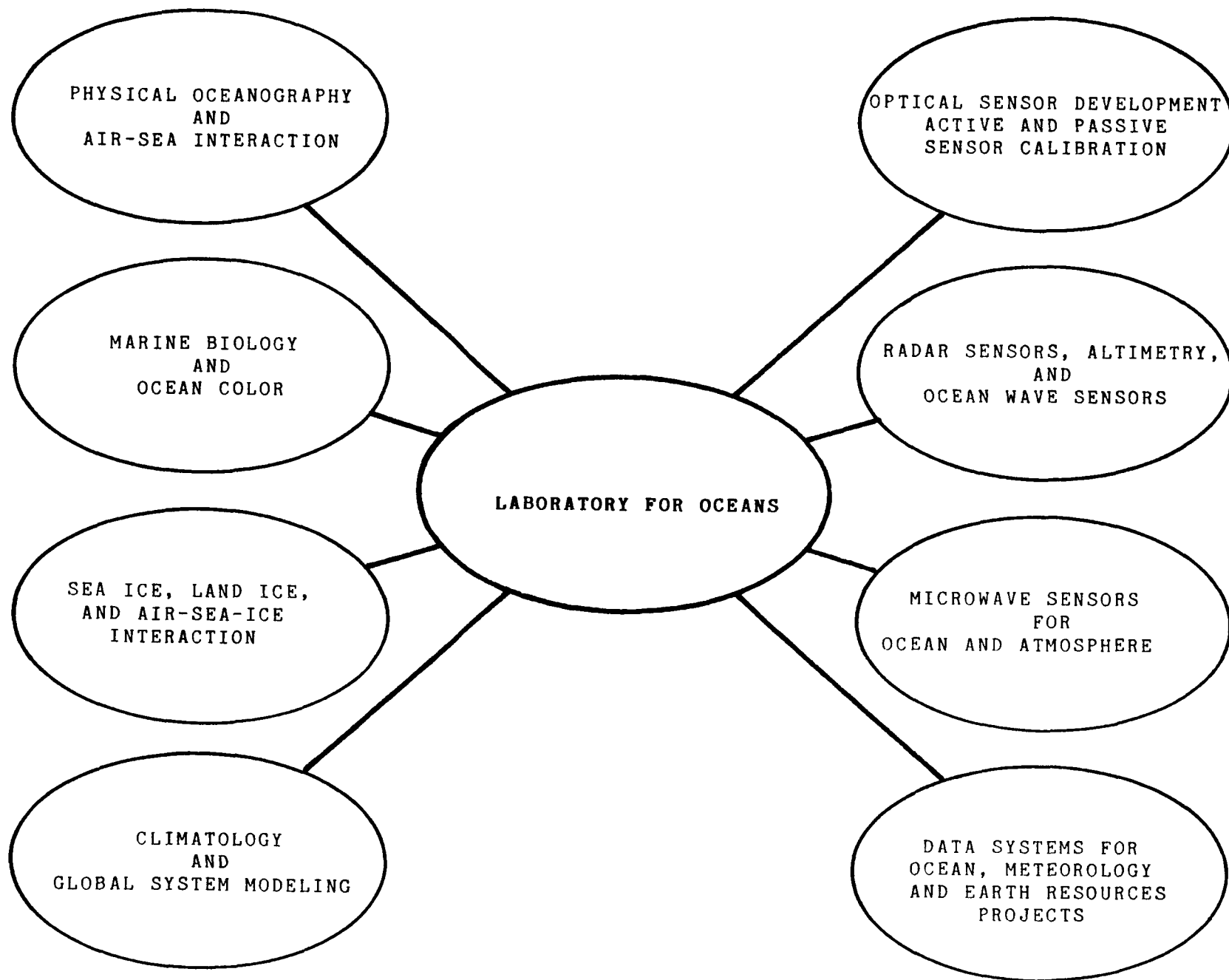
During the period covered by this report, the satellite data analysis activities in the Laboratory have been improved significantly by the availability of new computer data analysis facilities and software. The numerical modeling of oceans, and ocean-atmosphere-ice interactions have also made significant progress. In aircraft remote sensing, new instruments have been built and used in research, our lidar capability has grown, and new optical sensors have been used in research.

The activities of the Standards and Calibration Office is also expanding, as its capabilities become known and the importance of calibration is demonstrated through flight experience. The availability of a group with expertise in optical calibration is proving to be advantageous to instrument designers and instrument users; they no longer have to go through an independent learning experience in the field of calibration, but are able to draw on expertise, equipment and facilities that are kept available for the purpose and under continual improvement.

In our research activities, we have increased our participation in international observational programs, both as colleagues in research and as providers or experts in the use of satellite data and space sensor technology. This is valuable preparation for participation in future flight missions.

GODDARD SPACE FLIGHT CENTER
SPACE AND EARTH SCIENCES DIRECTORATE





670 - LABORATORY FOR OCEANS

Responsible for a broad program of research in ocean and cryospheric sciences, including the role of the ocean in climate and the chemical and biological components of the global system. The laboratory is also responsible for development and exploration in sensor technology, data systems and sensor calibration, and carries out aircraft and in situ observational programs to improve the fundamental knowledge of processes in the ocean, in sea ice and the physics of remote sensing. The laboratory collaborates in joint development, research and field observations with earth scientists from the Goddard Space Flight Center, and from universities and external research centers.

The Laboratory maintains competence through participation in research with members of the scientific and engineering communities and reflects the general needs for development of technology applications to research in the earth sciences.

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670.1 OCEAN DATA SYSTEMS OFFICE

Performs research and development of advanced direct readout data acquisition systems directed at meeting the needs of ocean, weather, land, climate and hydrology. Plans research and technology development, conducts systems studies, develops systems, maintains Laboratory for Ocean Color Facility (LOCF), and provides consultation and direct assistance to other government agencies including foreign government entities. Develops and manages major projects for the remote sensing of the earth and its environment and implements these projects in support of NASA, NOAA, or US AID programs.

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671 - OCEANS AND ICE BRANCH

Carries out research on oceanic and ice processes, and the roles of oceans and ice in global weather and climate. Develops remote sensing methods, algorithms and interpretations, to assist in sensor development and to demonstrate, through research applications and flight programs, the use of remote sensing in research on the Earth community on problems in oceanography, air-sea-ice interaction and glaciology. Carries out research in climatology in cooperation with scientists in meteorology and other neighboring fields. Works jointly with engineers and physicists on sensor development and the planning and execution of experiments. Serves as liaison between NASA and the oceanographic and glaciological research community by collegial interactions and participation in the joint research.

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672 - OBSERVATIONAL SCIENCE BRANCH

Responsible for theoretical and experimental research of observational systems and techniques associated with oceanic remote sensing. Performs instrument systems performance assessments. Plans and conducts laboratory and field measurements to improve the fundamental knowledge of remote sensing and to evaluate sensor systems and to quantify their performance. Assists other branches with field experiment planning, flight platform interfacing and data acquisition. Develops, maintains, and operates research facilities (i.e., wave tank, laboratory field standards, aircraft remote sensors, ground-based ozone and wind sensors) to obtain high quality measurements that support the development of new sensors and to obtain key scientific data. Establishes agreements for field data exchanges in support of scientific studies and satellite sensor calibration (i.e., vertical sounding of ozone, temperature and humidity, ocean waves and chlorophyll, etc.). Develops and furnishes algorithms to flight project personnel that convert the instrument observations into geophysical parameters.

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673 - STANDARDS AND CALIBRATION OFFICE

The Standards and Calibration Office is a hands on calibration activity within the Laboratory for Oceans which specializes in visible and near infrared calibration activities. The thrust of these activities is to provide Goddard investigators with improved radiometric calibrations for their experiments. Within the past 2 years the Office personnel have been involved in calibration source maintenance and development, flight source development and project and mission policy development. The Office is beginning an activity of vicarious calibration where a well calibrated instrument is used to observe a scene simultaneously with a satellite sensor to improve or verify the calibration of the satellite sensor.

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674 - EXPERIMENTAL INSTRUMENTATION BRANCH

The Experimental Instrumentation Branch is organized as a self-contained instrument development team. Its members have the basic skills that are necessary and sufficient for the design, project management, fabrication, assembly, and testing of electro-optical remote sensing instrumentation. Their skills are concentrated in electronic and computer engineering, optical and mechanical engineering, instrument design and drafting, model-building, and fabrication. They have a wide range of experience in instrumentation development for all application areas of the Earth sciences. They typically follow a task from its inception all the way through initial operational missions and data interpretation. This "in-house" development team is oriented toward flight project instrument development; primarily for NASA airborne remote sensing missions, but also for small spacecraft payloads. They supplement the flight mission development work with sensor system research tasks supported by the Director's Discretionary Fund, NASA/Headquarters RTOP tasks, and Small Business Innovation Research funding. They specialize in the development of lidar sensors, imaging spectrometers, radiometers, and laser altimeters.

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675 - MICROWAVE SENSORS AND DATA COMMUNICATION BRANCH

The Microwave Sensors and Data Communication Branch (MS&DCB) is a vertically integrated branch. The branch conceives sensor and system concepts, builds aircraft and ground based prototypes, develops interpretation algorithms and tests them on the data from the prototypes. After proving the feasibility of a given concept, we participate in the development of spaceborne missions and in the interpretation of the data from these missions. The intended results of all of the MS&DCB activities are application of space technology, particularly microwave and radio frequency, to advances in various Earth Sciences including Meteorology, Oceanography, Hydrology and Seismology. In order to be effective over so wide a range, we are staffed by technicians, engineers and physicists and we collaborate with Earth scientists from other branches, other divisions and outside of NASA.

<u>NAME</u>	<u>PROFESSIONAL TITLE</u>	<u>CODE</u>	<u>PHONE NUMBER</u>
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OCEAN TOPOGRAPHY EXPERIMENT (TOPEX) RADAR ALTIMETER

P-3

by

L. C. Rossi, D. W. Hancock, and G. S. Hayne (672)

Our involvement with the TOPEX Radar Altimeter allows us to contribute to the advancement of oceanographic research by participating in the NASA TOPEX Mission in the areas of space-flight hardware and ground data processing algorithm development.

We are assisting the Jet Propulsion Laboratory's (JPL) TOPEX Flight Project Office in the execution of the TOPEX Flight Mission relative to the requisite spaceflight hardware and supporting data reduction algorithms that will be required. Specifically, we are providing a spaceflight qualified Radar Altimeter capable of achieving the TOPEX Mission measurement precision requirement of 2-centimeters, and will evaluate its performance (Engineering Assessment) after launch and continuously during its 3-year mission operational period. We will be providing to JPL information about the calibration of the TOPEX Radar Altimeter. We will provide the specifications for the required data processing algorithms which will be necessary to convert the Radar Altimeter mission telemetry data into the geophysical data. We will participate in the validation of these geophysical data prior to their initial release to the TOPEX Principal Investigators and at periodic intervals during the TOPEX Mission.

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The stringent 2-centimeter precision requirement for ocean topography determination from space necessitated examining existing Radar Altimeter designs for their applicability towards TOPEX. As a result, a system configuration evolved using some flight proven designs in conjunction with needed improvements which include: 1) a second frequency or channel to remove the range delay or apparent height bias caused by the electron content of the ionosphere; 2) higher transmit pulse repetition frequencies for correlation benefits at higher sea states to maintain precision; and 3) a faster microprocessor to accommodate two channels of altimetry data. Additionally, examination of past altimeter programs associated data processing algorithms was accomplished to establish the TOPEX-class Radar Altimeter data processing algorithms, and the necessary direction was outlined to begin to generate these for the TOPEX Mission.

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) over the period FY83-FY86 completed the TOPEX Advanced Technology Model (ATM) Radar Altimeter. Since the last Activities Report, partial testing of the ATM provided evidence that 2-centimeter precision altimetry from space is achievable with the design concept chosen for the flight TOPEX Radar Altimeter. The necessary administrative arrangements to obtain the support of The JHU/APL for the development of this flight Radar Altimeter were accomplished during the first half of FY87, and their Flight Unit development efforts were initiated in the fourth quarter FY87. APL's major emphasis during the remainder of FY87 was the establishment of a new Radar Altimeter flight configuration

compatible with the TOPEX spacecraft selected by the Project and the conduct of Radar Altimeter Preliminary design activities. Development of the specifications for the flight TOPEX Radar Altimeter ground data reduction algorithms was initiated by GSFC's Code 672. The TOPEX Project sponsored Data Workshops with the TOPEX Science community concerning data processing were actively supported during FY87.

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MARS OBSERVER RADAR ALTIMETER RADIOMETER (MORAR)

by

L. C. Rossi, D. W. Hancock, and G. S. Hayne (672)

Our involvement with the Mars Observer Project will permit us to contribute to the advancement of the state of the topographic and hypsometric knowledge of Mars to a level of 10 meters or better over the surface of the planet Mars, to measure the microwave surface brightness temperature of Mars with an accuracy of 15 - 20 degrees Kelvin over the mission lifetime and a repeatability of + 2.5 degrees Kelvin over 24 hours, and to measure globally, surface returned power related to radar cross section (Sigma Zero) with an accuracy of 1 dB and a repeatability of .5 dB.

We are responsible for accomplishing the MORAR Hardware Development, Ground Data Processing, and the Mission Operations required by the MORAR Principal Investigator, Dr. David E. Smith/Code 620, whose scientific objectives are: a) to define globally the topography of Mars at sufficient vertical resolution and spatial scale to address both large-scale geophysical and small-scale geologic problems, and b) to obtain global surface electrical and scattering properties of the upper several centimeters of the Martian surface for assessment of the composition, physical state, and volatile distribution of the surface. 8100

The MORAR instrument development role was assigned to The Johns Hopkins University/Applied Physics Laboratory (JHU/APL) via a

NASA Defense Purchase Request to the U.S. Navy, the contracting agency for The JHU/APL. The Technical Monitoring of their activities is being accomplished by Code 820 personnel. The MORAR Ground Data Processing and Mission Operations will be accomplished within Code 672. MORAR Project Management is being accomplished by Code 672. MORAR Science will be performed both within the GSFC and various universities under the leadership of the Principal Investigator.

During FY87, the MORAR Experiment was confirmed as one of seven experiments to be conducted by the Mars Observer Mission. The MORAR Experiment Implementation Plan was established and approved by JPL. A Letter Agreement was implemented between the GSFC and the JPL to effect the MORAR. The MORAR Preliminary Design was initiated at The JHU/APL. The Interface Definition with the Mars Observer Spacecraft was initiated. The planning documentation for the Ground Data Processing System was initiated. The first key document defining the activities necessary to convert raw MORAR telemetry data into engineering parameters during the first of three Ground Data processing steps was established at the Preliminary level. Participation in the first MORAR Science Team meeting conducted in September 1987 was successfully accomplished. During the third and fourth quarters of FY87, the necessary replanning was initiated to accomplish the MORAR Investigation, in response to a revised Mars Observer launch date of 1992, instead of 1990. This replanning is still underway.

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BANGLADESH AGRO-CLIMATIC ENVIRONMENTAL
MONITORING PROJECT

by

C. Vermillion, H. Maurer, M. Williams, J. Kamowski,
T. Moore (670.1), W. Maksimovich (271.1),
H. Obler (271.3), E. Gilbert (675)

The Agro-Climatic Environmental Monitoring Project (ACEMP) is based on a Participating Agency Service Agreement (PASA) between the Agency for International Development (AID) and the National Oceanic and Atmospheric Administration (NOAA). The PASA was initiated on September 30, 1981, and the Project was completed September 30, 1987. A Memorandum of Understanding (MOU) between NOAA and NASA established NASA's function as the system developer/implementor.

In FY80, the Asia Bureau and Office of Federal Disaster Assistance (OFDA), worked closely to develop a funding mechanism which would meet Bangladesh's needs both for flood and cyclone warning capability and for application of remote sensing data to development problems. In late FY90, OFDA provided \$546,000 for a High Resolution Picture Transmission (HRPT) receiving capability to improve their forecasting accuracy for cyclones, flooding and storm surges. While that equipment is highly complementary and useful to the development purposes of the ACEM Project, it is primarily intended as a disaster prediction and preparedness measure.

The ACEM Project was designed to focus on the development applications of remote sensing technology. Through this Project,

AID provided to the Bangladesh Government (BDG) the equipment, technical assistance, and training necessary to collect and employ remote sensing data made available by satellites as well as hydrological data obtained from data collection platforms placed in major rivers. The data collected will enable the BDG to improve the management of its natural resources.

A Direct Readout Ground Receiving Station for Satellite data was installed at SPARRSO in Dhaka in 1978. This facility was substantially augmented in May 1985 to include digital processing, user and system operation and maintenance training, and a proper operating environment. An Installation Ceremony was held in Dhaka on May 8, 1985.

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**NASA FOLLOW-ON TO THE BANGLADESH AGRO-CLIMATIC
ENVIRONMENTAL MONITORING PROJECT**

by

C.Vermillion, H. Maurer, M. Williams (670.1),
M. DesJardins (612), E. Mollo-Christensen (670),
C. Mason (674), A. Kerber (623),
J. Gervin (400.6), J. Elrod (671)

This describes the NASA responsibility and activities for the Follow-on to the original Agro-Climatic Environmental monitoring Project (ACEMP) which was completed during 1987. The activities of the NASA Follow-on to the ACEMP are defined by Amendment 3 of PASA BAN-0046-P-CC-1967-00 between the U.S. Agency for International Development (USAID) and NOAA, and a Memorandum of Understanding (MOU) between NOAA and NASA. These agreements will expire November 30, 1988.

The following schedule is for the five training sessions which comprise the NASA ACEMP Follow-on:

August 29 - September 10, 1987	Agrometeorology
April 2 - 14, 1988	Meteorology of Severe Storms Using GEMPAK
June 11 - 26, 1988	Satellite Oceanography
September 17 - 29, 1988	Hydrology
November 5 - 17, 1988	Meteorology with TOVS

The objective of the Follow-on is to train Bangladesh Government staff in the use of satellite data for remote sensing applications. This activity also encourages the scientific connection between NASA/Goddard Space Flight Center and The Bangladesh Space and Remote Sensing Organization (SPARRSO).

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FIJI SOUTH PACIFIC SEVERE STORM DETECTION
AND WARNING SYSTEM PROJECT (SPSSD/WS)

by

C. Vermillion, H. Maurer, M. Williams, J. Kamowski,
T. Moore (670.1), W. Maksimovich (271.1), A. Hasler (612.0)

In August 1986, a South Pacific Severe Storm Detection and Warning System (SPSSD/WS) was installed by NASA at the Fiji Meteorological Service (FMS) in Nadi, Fiji. The SPSSD/WS Project was funded by the U.S. Agency for International Development (U.S. AID) and administered through the National Oceanic and Atmospheric Administration (NOAA).

The system consists of a 6.1 meter parabolic dish antenna, a satellite ground station, computer and image processing facilities. The system allows tracking of all South Pacific tropical cyclones with real-time, high resolution reception of visible and infrared cloud images from both the Japanese Geostationary Meteorological Satellite (GMS) and the U.S. Geostationary Operational Environmental Satellite (GOES-WEST).

Training was also provided in system usage and operations. A course in Satellite Meteorology was also conducted at FMS by NASA. On August 19, 1986, the system was formally accepted and handed over officially to the Fijian Government.

In December 1986, the U.S. AID Office of U.S. Foreign Disaster Assistance (OFDA) commissioned an evaluation of the SPSSD/WS. The report recognized the system as one of the most advanced of its kind in the Pacific Basin; that it has functioned

successfully since installation with only minor interruptions, and that it has become the prime tool in supporting the FMS' role as the regional tropical cyclone warning center for the Southwest Pacific. However, the report also noted that there are needed enhancements to the system. This, therefore, led to a follow-on program with U.S. AID.

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**NASA FOLLOW-ON ON THE FIJI SOUTH PACIFIC SEVERE STORM
WARNING SYSTEM PROJECT (SPSSD/WS)**

BY

C. Vermillion, H. Maurer, M. Williams, J. Kamowski,
T. Moore (670.1), W. Maksimovich (271.1), A. Hasler (612.0)

In December 1987, a Follow-on Participating Agency Service Agreement (PASA) was signed directly with the U.S. Agency for International Development (U.S. AID). This Follow-on will implement needed systems enhancements of the satellite ground station installed under the previous SPSSD/WS project. These enhancements include the purchase and installation of an Uninterruptible Power Supply (UPS) and lightning protection unit, hardware modifications to provide system redundancy and increased data storage capacity, software modifications for the new Japanese GMS digital data, upgrades of the image processing software, and both hardware maintenance and tropical cyclone analysis training, and a non-renewable grant to provide emergency field repairs and replacement/spare parts.

In March 1988, the UPS and lightning protection unit was installed at the Fiji Meteorological Service by NASA personnel. A tape recorder and demodulator has been shipped to Fiji to record the new digital GMS data. Data tapes are not yet available from the Japanese Meteorological Service of the new digital format. This data is required to test the GMS digital software being developed for the Fiji SPSSD/WS facility.

Installation the remaining equipment upgrades, GMS digital software, image processing upgrades and maintenance training are scheduled for July 1988.

The tropical cyclone training and Fiji Grant will be implemented in FY89 pending provision of remaining funds from U.S. AID.

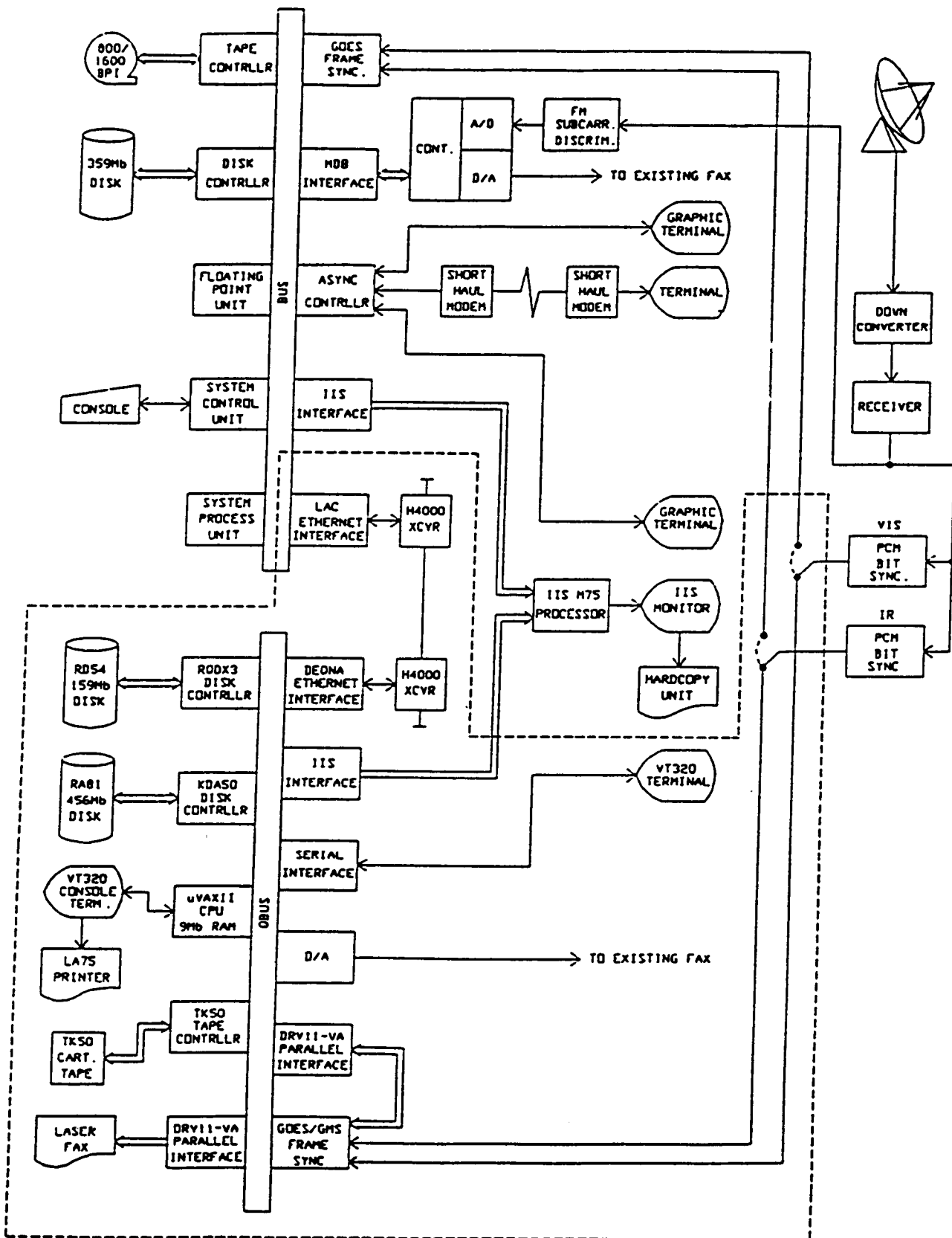


Figure 1. SPSSDWS and Enhancement Project Systems Configuration - Preliminary Design

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MONOCULAR ELECTRO-OPTICAL STEREO SCANNER

P-2

by

C. Vermillion, H. Maurer (670.1), V. Salomonson (620),
C. Cote (610), J. Catena (501),
H. Rampariyan (636), Dr. J. Smith (623)

The Monocular Electro-Optical Scanner (MEOSS) is an experiment on the Indian Space Research Organization (ISRO), Stretched Rohini Satellite System (SROSS) two satellites were launched by the ISRO Advanced Satellite Launch Vehicle (ASLV) from Shriharikota, India. The MEOSS payload is a Federal Republic of Germany (FDR) project managed by the Deutsche Forschung-und Versuchsanstalt fuer Luft und Raumfahrt (DFVLR) in Oberpfaffenhofen, FDR.

In November 1986, GSFC Space and Earth Sciences Directorate, Code 600, responded to an Announcement of Opportunity (AO) from DFVLR (German Aerospace Research Establishment) for use of the MEOSS to form stereographic images over selected test sites in the Western U.S. Formal approval was received in July 1987 in a letter from F. Lanzl to V. Salomonson. A rescheduled launch is expected for June 1988. The experiment requires the use of the Goldstone Facility for data readouts over the U.S. The Goddard Mission Operation Manager is John Catena. The Principal Investigator is Dr. Vincent Salomonson, and Co-investigators are Charles Cote, Charles Vermillion, Dr. H. Ramapriyan, and Dr. J. Smith.

MEOSS is a single optics and single spectral band camera. Three CCD's working in pushbroom mode are mounted perpendicular to the flight direction on a common focal plate. Their oblique views of plus and minus 23 degrees forwards and backwards as well as nadir

oriented lead to threefold stereoscopic images. In contrast to other stereo scanners like SPOT, this principle allows a nearly simultaneous generation of all three images of a stereo triplet. The time gap between the forward and aft looking images guarantees constant illumination conditions. The ground resolution of MEOSSE will be 52 by 80 meters ground pixel size, height resolution of 55 meters and swath width of 255 kilometers. The drifting ground coverage pattern of MEOSSE is unique compared to polar orbiting satellites and will allow images of an area to be taken at different times of the day. A scene will consist of 3144 scan lines, with each having 3236 pixels.

The data will be received by the Deep Space Network of JPL Goldstone and mailed to Code 670.1 of Goddard. Level 1 data will be produced by Code 670.1, i.e., raw data on CCT with appended calibration data. Code 636 will receive Level 1 data from Code 670.1 and will register the scenes and produce bi-directional and stereo imagery. Code 630.2 will receive data for storage and distribution from a central archive. The Experimenters, i.e., Code 623 of GSFC, plus the University of Arizona, and the University of California will receive the data from Code 630.2 for scientific analysis. There is an estimated data volume of two/three scenes every 2 to 6 months. This would result in a minimum of 12 scenes and a maximum of 54 scenes. Each scene represents about 2 minutes of data acquisition time by the payload.

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TROPICAL RAINFALL MEASUREMENT MISSION

7-4

by

T. T. Wilheit (675)

It has long been noted that anomalies in the sea surface temperature (sst) in the tropics are strongly correlated with climate in the temperate latitudes on a seasonal time scale. The best known case is the El Nino-Southern Oscillation (ENSO) anomaly which has been correlated with a great many weather anomalies in the temperate regions. This correlation is presumed to occur because the sst anomaly produces an anomaly in the precipitation which, through its release of latent heat, produces global scale anomalies in the average atmospheric pressure and temperature fields. Our ability to measure the global sst and the atmospheric pressure/temperature patterns has made great progress. However, at this point, we measure rainfall, the putative connection between the two, very poorly.

The Tropical Rainfall Measurement Mission (TRMM) was conceived to fill this gap. The TRMM spacecraft would fly in a low inclination, (about 35 degrees), orbit which would concentrate the sampling in the very important tropical latitudes. The precession of such an orbit would enable observations at all times of the day over the span of a month which would permit corrections for the diurnal cycle of precipitation which is quite marked in parts of the tropics. The payload of the TRMM spacecraft, shown in the attached figure, is carefully designed to provide accurate measurements of rain. It consists of

microwave radiometers, a microwave radar and visible/infrared radiometer. The two types of microwave instruments provide direct measurements of the hydrometeors, each having strengths which compensate for weaknesses of the other. The vis/ir instrument provides a connection to the long-time series of vis/ir measurements from polar and Geosynchronous spacecraft which are currently the best available source of global rainfall estimates. The accuracy requirement on the measurement is estimated to be of the order of 1 mm/day for a 1 month average over a 5 degree square. An error model which combined both instrumental and sampling error suggests that the TRMM measurements will yield an accuracy of about 1.2 mm/day over ocean but degrades to about 1.7 mm/day over land.

The TRMM is currently in a phase A (feasibility) study. The principal scenario under consideration is that the government of Japan would provide the radar instrument and would launch the spacecraft; the United States would provide the remainder. The current target is for a FY90 new start approval and a 1994 launch date which would permit overlap with the Tropical Oceans Global Atmosphere (TOGA) program which ends in 1995.

The possibility of a Space Station follow-on for TRMM is also being studied. Activities are underway to produce three instrument proposals and a science proposal which would tie them together in response to the Eos Announcement of Opportunity.

The Microwave Sensors and Data Communication Branch is deeply involved in the TRMM. We were part of the team which developed

the original concept and continue to work on the Phase A study. We provide the principal expertise in the microwave measurement of precipitation and conduct research to develop algorithms for the retrieval of rain rates from the TRMM measurements.

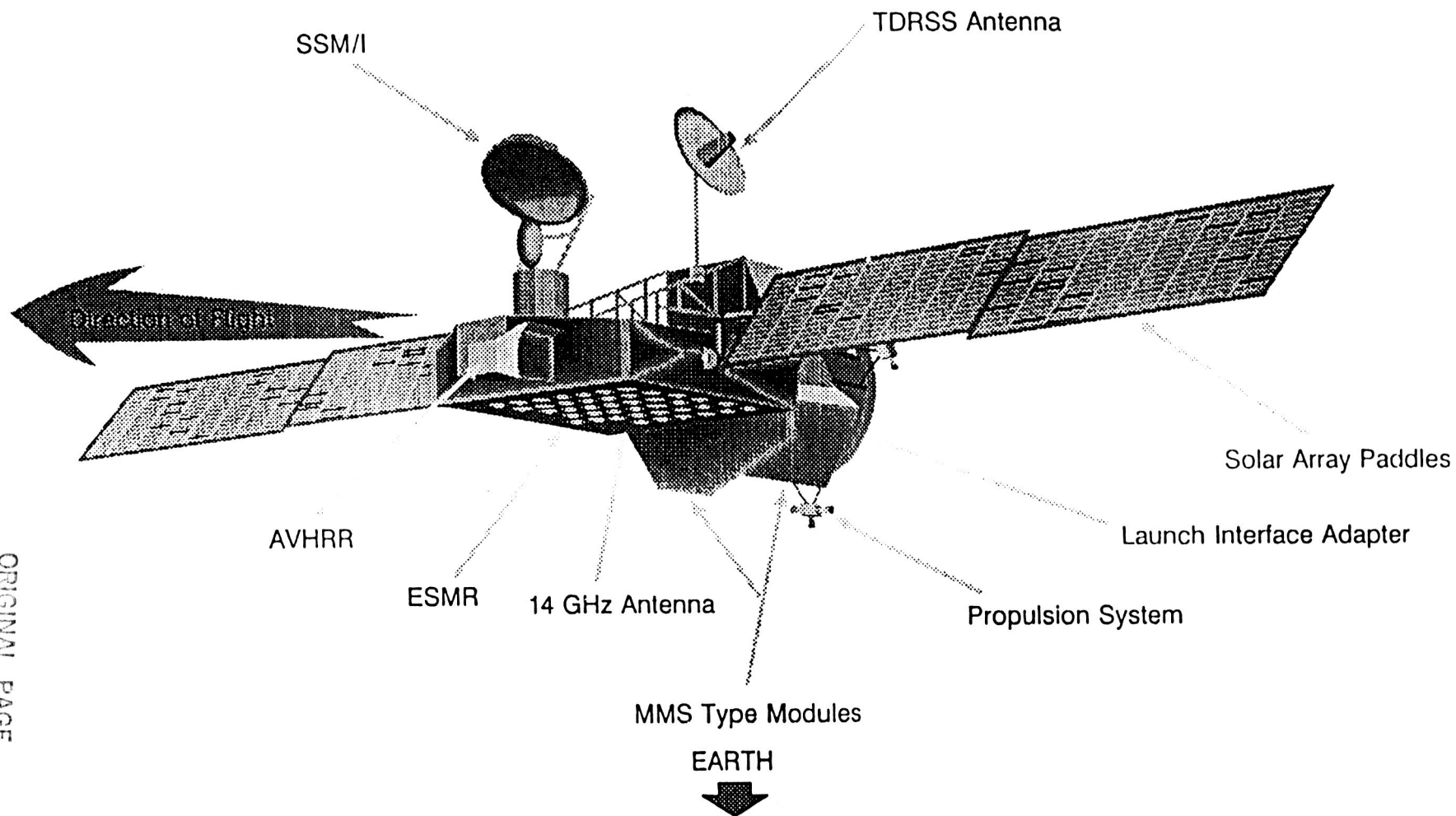


Figure 1. Tropical Rain Fall Mission (TRMM)
Instrument Orientation

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SPACEBORNE METEOROLOGICAL RADAR STUDIES

by

R. Meneghini (675)

The objective of the work is to study various radar designs and methods for the estimation of rainfall parameters from space. An immediate goal is to support the development of the spaceborne radar that has been proposed for the Tropical Rain Measuring Mission (TRMM). The TRMM radar, which will be the first meteorological radar to be flown in space, has the unique capabilities for vertical profiling of the storm cell and for quantitative rainfall estimates over land. To take full advantage of the radar requires a detailed understanding of its performance and the manner in which these data can be combined with radiometric measurements.

The effort is divided into two activities: a cooperative airborne rain measuring experiment with the Radio Research Laboratory of Japan (RRL), and the modelling of spaceborne weather radars.

An airborne rain measuring experiment was conducted at Wallops Flight Facility in 1985-1986 using the dual-wavelength radar/radiometer developed by RRL. The data are presently being used to test a number of methods that are relevant to spaceborne weather radars. An example is shown in Fig. 1 of path-averaged rain rates as estimated from three methods: the standard

reflectivity rain rate method (Z-R), a dual-wavelength method, and a surface reference method. The results from the experiment have shown for the first time the feasibility of using attenuation methods from space. We can also begin to study how the various methods can be used to improve the accuracy and extend the dynamic range of rain rate estimation. A second phase of this experiment is planned for 1989. Toward this end, several upgrades of the instrument are being made for its installation in a high-altitude aircraft.

The purposes of the modelling are twofold: to understand in a quantitative manner the relationships between a particular radar design and its capability for estimating precipitation parameters; to help devise and test new methods. The models are being used to study the impact of various TRMM radar designs on the accuracy of rain rate estimation as well as to test the performance of range-profiling algorithms, the mirror-image method, and some recently devised graphical methods for the estimation of the drop size distribution.

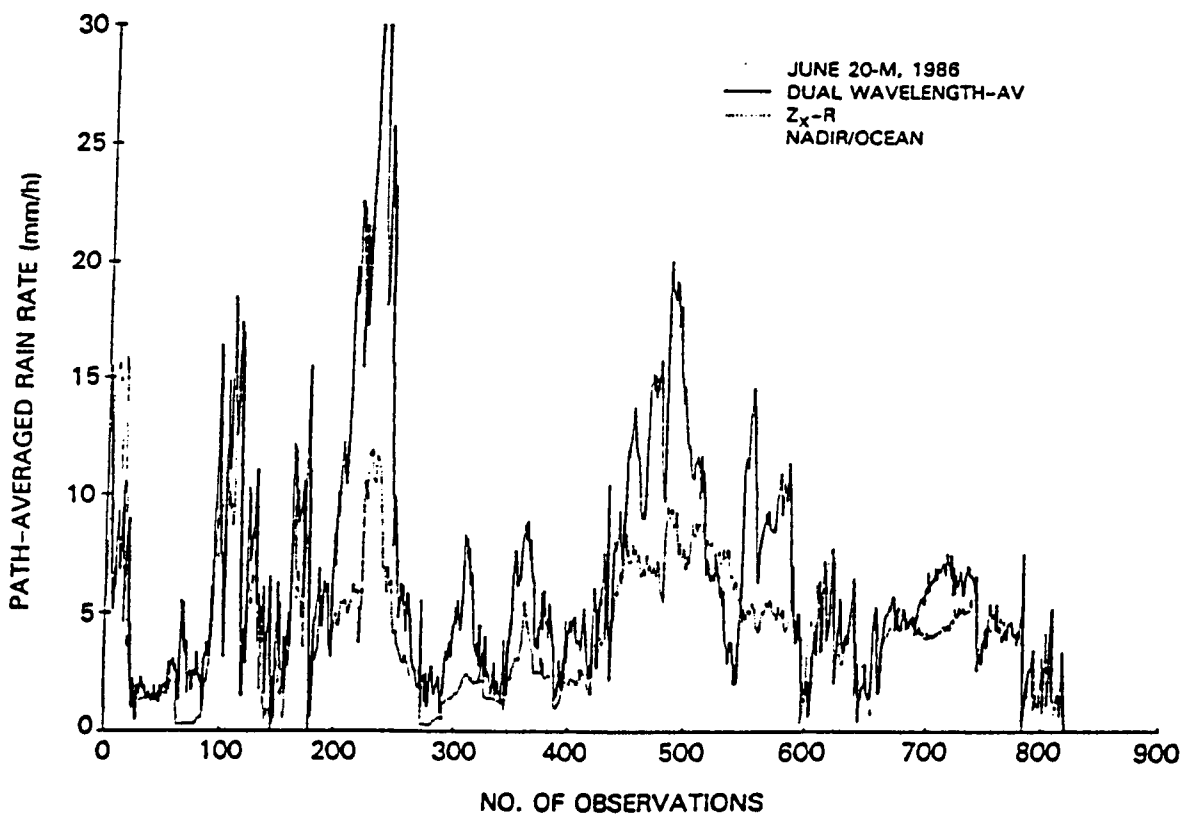
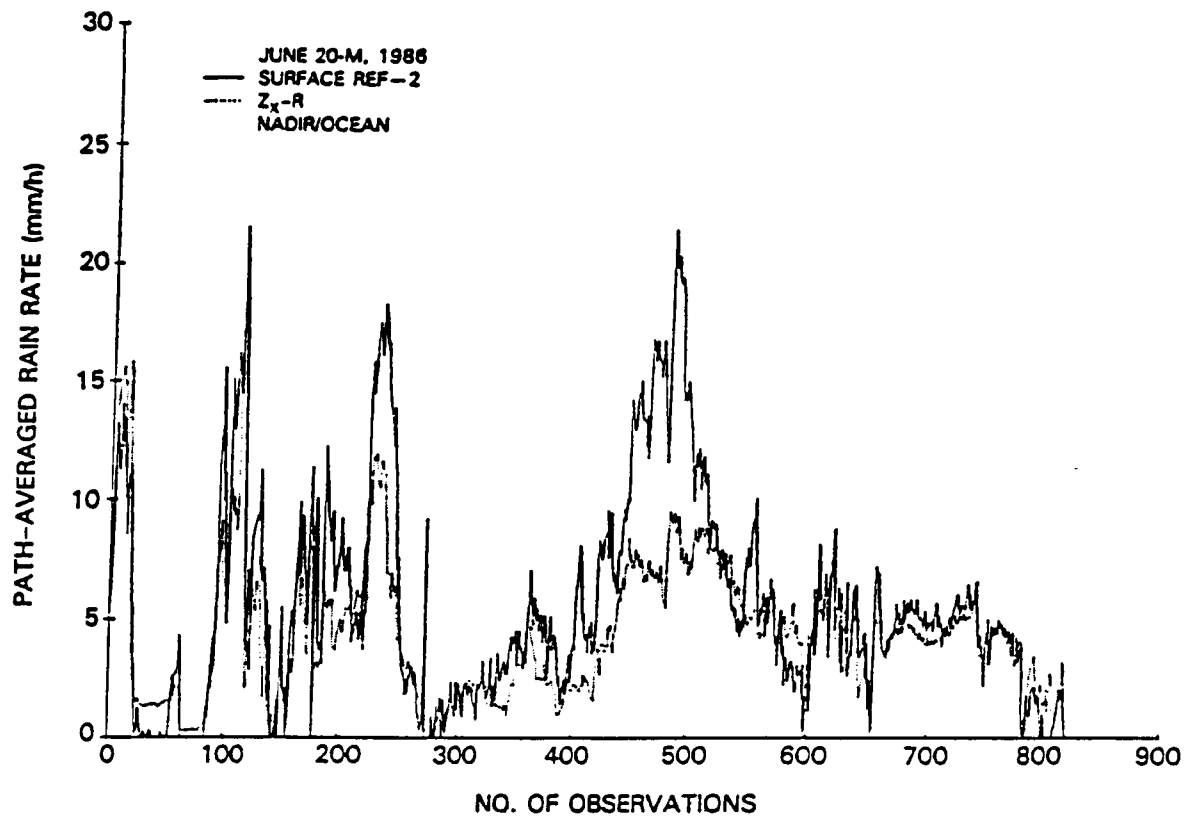


Figure 1. Path-Averaged Rain Rates

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ADVANCED ALTIMETRY

by

C.L. Parsons, S.A. Bailey, D.E. Hines,
D.W. Shirk, C.W. Wright (672) and A.R. Selser (822.2)

The radar altimeter being developed for the Ocean Topography Experiment (TOPEX) will have an inherent instrument precision of 2-3 cm. This is smaller than or of the same order of magnitude as the effects from other sources of uncertainty in satellite altimetry, such as the ionosphere, barometric fluctuations, water vapor absorption, etc. While some minor refinements may be possible in the future, major geophysical advances could be made if altimetric measurements over a wide swath of the Earth's surface were possible. Beginning in January 1986, the NASA Headquarters Oceanic Processes Branch is supporting a 3-year investigation of the technological issues inherent in the precision measurement of topography from spaceborne platforms at angles off-nadir. Also, this RTOP, 161-1006, has as an additional goal the identification and development of a future space mission using the advanced wide swath radar altimetry under study. Much progress has been made toward this latter goal, and this is described in another activity report in this volume entitled "Eos Advanced Altimetry."

To explore the off-nadir measurement of topography, a flexible, airborne radar instrument system is being developed. Its hardware design is now complete, and it consists of the following

subsystems. The antenna selected is a dielectric lens of .894 m diameter. At an operating frequency of 36 GHz, it has a gain of 47.5 dB and a one-way beamwidth of .6 degrees. Most importantly, it can be used to transmit and receive at angles up to 12 degrees from its axis without major beam pattern degradation from optical aberrations.

The RF subsystem uses phased-locked oscillators, FET solid-state amplifiers, and "times four" frequency multipliers to develop a transmit signal at a frequency of 36.0 GHz and a local oscillator signal at a frequency of 35.4 GHz. The transmit signal is switched on and off by a PIN diode switch at a PRF of 200 Hz and with a pulse width of 10 ns. RF amplification of the transmit pulse is achieved from a 1.5 kw Varian Extended Interaction Amplifier, and a waveguide network distributes the transmit and local oscillator signals to five circulator/feed horn/receiver assemblies. Each receiver detects the backscattered RF signal and downconverts to an intermediate frequency of 600 MHz.

Lecroy 6880 digitizers under computer control digitize the five receiver outputs. The digital subsystem consists of six single-board Heurikon processors. Each has specific responsibilities; communication with the other processors is achieved through bus interfaces. One executes UNIX and is responsible for coordinating the activities of the others, which use VRTX, a real-time operating system. With this modularized, highly flexible design, the total functioning of the radar system is under computer control. This makes the instrument, the Aircraft

Multibeam Radar Altimeter (AMRA), a unique tool for studying altimetry at angles from nadir to 12 degrees.

At this time, the instrument construction continues with final system integration planned for November 1988. The system will be installed in the Wallops P-3 research aircraft for engineering evaluation and test flights in the Spring of 1989. It is hoped that the system will be ready for use in field missions by April 1989. One experiment that the AMRA might support is the spring window of SYNOP. Also, the measurement of the backscattering cross-section of selected portions of the Earth's surface at 36 GHz is of considerable -importance to several proposed Eos investigations. AMRA should be able to make these needed measurements.

AMRA Design Performance Summary:

Antenna -	type	dielectric lens
	diameter (m)	.894
	gain (dB)	47.5
	beamwidth (deg)	.6 (one-way)
	look angles (deg)	0-12
	no. of beams	5
RF -	frequency (GHz)	36.0
	power (kw)	1.5
	bandwidth (MHz)	220
	pulse width (nsec)	10 nom.(5 goal)
	pulse rate (Hz)	200
Signal Processor -	sampling rate (GHz)	1.3
	samples/waveform	128
	tracker type	variable

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EARTH OBSERVING SYSTEM (Eos) ADVANCED ALTIMETRY

by

C. L. Parsons and E. J. Walsh (672)

In the post-TOPEX era, satellite radar altimeters will be developed with the capability of measuring the earth's surface topography over a wide swath of coverage, rather than just at the satellite's nadir. The technological issues inherent in the off-nadir measurements are being studied through RTOP 161-10-06. An Aircraft Multibeam Radar Altimeter is being developed under this RTOP, and it is described in another report in this volume entitled "Advanced Altimetry (RTOP 161-10-06)." In parallel, the identification of potential spacecraft flight missions in the future has also been pursued. The best opportunity was found to be the Earth Observing System (Eos). Through agency-level program initiatives such as Mission to Planet Earth, Eos has become the primary platform of opportunity for the earth sciences in the 1990's, and the recent Announcement of Opportunity (No. OSSA-1-88, January 19, 1988) is convenient and timely. The progress in RTOP 161-10-06 makes an Eos proposal at this time possible.

A joint proposal is now in preparation. Participants in this activity are from the GSFC, the Jet Propulsion Laboratory, and the Federal Republic of Germany. The participants have mutually agreed to this collaborative effort because of the interdisciplinary nature of Eos. It is felt that an instrument system

that has a broad appeal to the earth sciences community stands a much better chance of being selected as an Eos instrument. Consequently, the Topography and Rain Radar Imager (TARRI) will be proposed as a system that has the capability to profile the Earth's topography regardless of the surface type. The horizontal and height resolutions of interest are obviously significantly different over land, ice, and water; but, the use of radar to provide an all-weather observation capability is applicable to the whole earth.

It is proposed that the instrument development responsibilities will be shared by the participants. The Land Mode will use a scanning beam produced by a 12 m x 1 m phased array to measure the slant range in the cross-track direction over a 20 km swath. The Ocean Mode will use a "parked" beam from the phased array as the transmitter and two parabolic dishes separated by a fixed boom as an interferometric receiver. The two-dish interferometric altimeter approach has been described in the literature by Bush, et al. ("An Analysis of a Satellite Multibeam Altimeter," Marine Geodesy, Vol. 8, Nos. 1-4, 1984, pp. 345-384). Both modes operate at a frequency of 36 GHz. The Ocean Mode dishes have multiple feed horns boresighted in pairs; at present, a maximum number of five illuminated spots on the surface is envisioned. At a spacing of 25 km, this will yield topographic information over a total swath width of 100 km.

The scientific guidance for the design and development of this

instrument and the eventual scientific utilization of the data produced by the TARRI will be provided by seven science teams. All are responsible to the Principal Investigator and two Deputy Investigators. The teams are formed around scientific disciplines and are titled: Geology/Geophysics, Hydrology/Rain, Oceanography, Ice/Snow, Geodesy/Orbit/Attitude, Cartography, and Surface Properties/Techniques.

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WIDE BAND DATA COLLECTION SYSTEM

by

J. M. Turkiewicz (675)

The Incorporated Research Institutes for Seismology (IRIS) approached NASA Headquarters in 1986 about the need to collect data daily from seismic stations around the world as part of the Earth Observing System (Eos) mission. A typical IRIS Seismic Station generates 16 Megabytes of data per day under background conditions, and up to 24 Megabytes of data per day when there is seismic activity. A competitive contract was won by ORI to perform a preliminary design study which would yield a design to the block diagram level, and provide a link analysis, size, weight, power and cost estimate. Technical Report No. 2773, "EOS WIDEBAND DATA COLLECTION SYSTEM: BLOCK DIAGRAM, LINK ANALYSIS, SIZE, WEIGHT, POWER AND COST ESTIMATES," was delivered on September 30, 1987.

The following is a summary of the Preliminary Design Parameters of the Wide Band Data Collection System:

Concept

1. Spacecraft

WBDCS: fixed earth coverage antenna, 7 GHz receiver, 8.5 GHz transmitter, programmable controller for generating commands to stations, power converter

Eos: Data multiplexer, storage for up to 2 orbits (0.4 Gbytes) of seismic data, communications link to TDRSS

2. Seismic stations - land based

Active track antenna, 1.2 m diameter, similar to Marisat Tracking and Command Receiver at 8.5 GHz Storage for up to 24 hours of seismic data (24 Megabytes) Transmitter, 10 watts, 7 GHz

3. Operation

WBDCS: Commands seismic stations in sequence to transmit data Receives seismic data, and sends it to Eos Data System

Eos: Multiplexes seismic data with Eos data Stores multiplexed data Transmits multiplexed data to TDRSS

TDRSS: Relays data to TDRSS ground station

TDRSS ground station: Strips out seismic data Sends data to IRIS Data Center

Note: Daily collection of data by Eos means some of the data are almost 24 hours old before they are received by Eos. An additional maximum delay of 218 minutes (two orbits) may occur before the data are transmitted to TDRSS and relayed to a TDRSS ground station. There may be additional delay at the TDRSS ground station before the seismic data are stripped from the Eos data and sent to the IRIS Data Center.

COMMUNICATIONS LINKS - Summary

<u>DOWNlink *</u>	<u>WBDCS tracking beacon and command transmitter</u>
frequency	8.5 GHz
command bit rate	100 bits per second
margin	20 db
<u>UPlink *</u>	<u>Collect data from seismic stations</u>
frequency	7 GHz
bit rate	1 Megabits per second
modulation	quadriphase with rate 1/2
	convolutional coding
margin	2 db for 10 ⁻⁷ BER

Note: 24 hours of data can be collected from each station during one satellite pass, leaving the second pass during a 24-hour day for repeat transmissions as required.

* One earth coverage 80 cm diameter antenna for UPlink and DOWNlink

TYPICAL LAND BASED GROUND STATION

Antenna	1.2 m diameter (similar to Marisat) Active tracking at 8.5 GHz Transmit at 7 GHz
Receiver	8.5 GHz: tracking beacon signal from Eos commands at 100 bps from WBDCS on Eos
Transmitter	7 GHz, 10 watts
EIRP	45.4 dbw
Cost	Order of magnitude - \$100K.

WIDE BAND DATA COLLECTION SYSTEM - SUMMARY Cost, Mass, Volume, Power

Space Segment

RDT & E	\$9.17 M	1	19%
First Unit	\$1.86 M	1	49%
Mass	18.5 kg		
Power	54 watts		
Volume	17,641 cm ³	0.02 m ³	
Antenna	fixed metal reflector, 80 cm diameter, with feed horn		

Ground Segment

Order of magnitude cost for land based Uplink and DOWN- link communications with Eos	-\$100K, includes 1.2 m diameter active track antenna
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CONCLUSION

The Wide Band Data Collection System is to be funded by Eos for further development to a space qualified system.

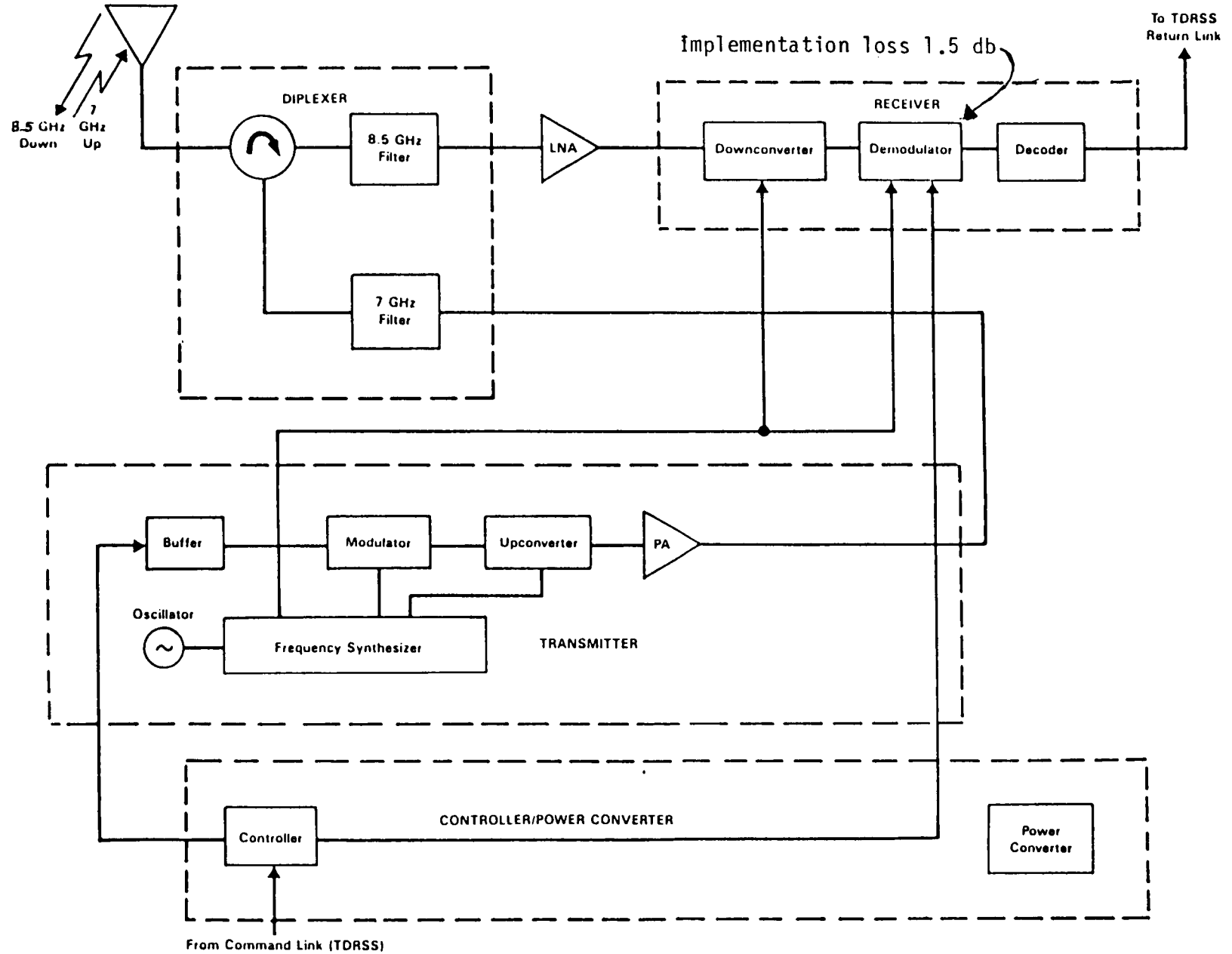


Figure 1. WBDCS Space Terminal Block Diagram

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CALIBRATION SUPPORT FOR THE EARTH
OBSERVING SYSTEM PROJECT

by

B. W. Guenther (673)

The Earth Observing System Project (Eos) program guidelines establishes significantly more stringent requirements on calibrations of instruments. This requirement is driven by the need for long-term continuity of acquired data sets and the use of measurements in interdisciplinary investigations. Personnel from the Standards and Calibration Office have been supporting the Program and Project in interpreting these goals into specific requirements.

Contributions to Eos have included participation in the Panel of Experts which produced a List of Consensus Items Necessary for Accomplishing an Accurate Calibration and Suggested Eos Project Calibration Policy, and drafting the Announcement of Opportunity and Bidders Information Package positions on instrument calibration and data product validation. We have also provided technical staffing to the NASA delegates to the Committee on Earth Orbiting Satellites (club of space-faring nations) for the standing working group on Calibration and Data Validation.

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OCEANOGRAPHIC WIDE FIELD SENSOR

by

R. G. Kirk (671)

The Oceanographic Wide Field Sensor (SeaWiFS) science project will provide measurements of ocean color from space to which will support research into: a) the character of ocean physical and biological processes; b) to assess the global oceanic biomass; and c) to better understand the role of oceanic processes in modulating the Earth's biogeochemical cycles, including the CO₂ cycle as it is affected by fossil fuel combustion. This research will be conducted by NASA as well as the outside scientific community through an Announcement of Opportunity process.

The present work extends previous work to study the feasibility of an ocean color mission using the proposed compact Wide-field Sensor (SeaWiFS) and the EOSAT Corporation's LANDSAT-6 satellite.

We conducted a Phase A study which defines a NASA Facility Data System and accompanying Science Program for the EOSAT Company's commercial ocean color instrument called "SeaWiFS" to be launched on board LANDSAT-6 in 1991. Codes 670, 630, and 620 participated in the study. A current working group chartered jointly by NASA Headquarters and EOSAT is providing final baseline characteristics.

Next year a GSFC Project will work with EOSAT and the Joint NASA/EOSAT Working Group to integrate the commercial and science

baseline and develop a detailed NASA plan for implementation of a Science Data System for a FY91 SeaWiFS launch on LANDSAT-6. the proposed concept assumes NASA input to the SeaWiFS specification and operational scheduling, and the receipt of worldwide, continual taped ocean color data from EOSAT, as well as direct read out of East Coast real time coverage at GSFC. EOSAT will forward taped ocean color data to a data processing system at GSFC. GSFC, in turn, will process all received data to scientifically useful form on optical disk format and distribute it to the research community in conjunction with the NASA Ocean Data System. Research community users include: NASA Principal Investigators, Announcement of Opportunity participants, and other researchers through the NSSDC.

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THE EARTH RADIATION BUDGET EXPERIMENT

by

A. T. Mecherikunnel (670.1)

DATA ANALYSIS: The Earth Radiation Budget Experiment (ERBE) data studied at present are:

1. The solar data from solar monitors of the ERBE onboard ERBS, NOAA-9, and NOAA-10 spacecraft.
2. Investigation of the ¹colocated satellite altitude irradiances from ERBS and Nimbus-7 Earth Radiation Budget measurements.
3. Analysis of the time- and space- averaged radiation budget products from ERBS and Nimbus-7 ERBE.

1. Solar Data from ERBS, NOAA-9, and NOAA-10.

The solar total irradiance data obtained by the ERBE solar monitors serve as a calibration check on the earth viewing radiometers, as well as provide the experimental value of the solar constant needed in the net radiation computations.

Solar data from the ERBE experiments are analyzed, and a comparative study of the data with solar measurements made for the same period from Solar Maximum Mission Active Cavity Radiometer Irradiance Monitor experiment and the Nimbus-7 Earth Radiation Budget Measurements. The data sets available from the ERBE for a period of 2 years from launch are archived at the NSSDC, GSFC, and are available to the scientific community for investigations.

2. Investigation of the colocated satellite altitude irradiances from ERBS and Nimbus-7 Earth Radiation Budget Measurements.

The sun-synchronous, near-local-noon Nimbus-7 satellite has coincident orbital intersections with the non-sun-synchronous ERBS spacecraft. The objective here is to compare the WFOV and MFOV (wide and medium field-of-view) observations of the ERBS/ERBE, and the Nimbus-7 ERB data sets at the points of their orbital intersections.

3. Globally and zonally averaged ERBE/ERBS data.

Investigations of the globally and zonally averaged ERB obtained from the ERBS scanner, MFOV and WFOV and the Nimbus-7 WFOV is being carried out to assess the sensor performance.

The data analysis is carried out in collaboration with the Nimbus-7 ERB processing team, managed by H. Lee Kyle, Code 636. These studies have significantly contributed to the ERBE sensor calibration and performance evaluation, and data validation. Besides, it is useful to assess the relative accuracy of the Nimbus-7 ERB data sets (began in 1978), and to establish long-term earth radiation budget data sets for scientific investigations.

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LUNAR OBSERVER LASER ALTIMETER

by

J. L. Bufton (674)

The exploration and characterization of the terrestrial planets and their satellites requires an accurate understanding of their topography. Understanding the global topography of the Moon is especially important for answering questions concerning lunar origin and evolution. Many outstanding problems in lunar science can be addressed with high resolution topographic data. Some of these include the precise figure of the Moon, the nature of gravity anomalies, and the thermal and loading histories of major impact basins. Others are the styles and volumes of volcanic eruptions, measurements of modification processes, and problems associated with impact catering. The correlation of lunar surface geochemical processes and topography has been examined only in limited equatorial regions, and requires further assessment. Finally, information necessary for the optimal placement of lunar bases will require accurate knowledge of the local relief of the lunar surface.

The severe power, mass, size, and data-rate limitations imposed by the Lunar Geoscience Observer (LGO) and other Observer-class missions are major challenges for all instruments capable of measuring topography. A radar altimeter that meets these strict requirements could obtain a global perspective of lunar topography with a few kilometers spatial resolution and 10 m vertical resolution from a lunar orbit of 100 km. Many of the

problems listed above, however, require topographic data with spatial resolution of 100 m or better and vertical resolution of 1 m. The only means of obtaining such high-resolution data is with the small footprints, short pulses, and precise timing available with laser altimeters. The instrument heritage and scientifically useful data from the three successful missions of the APOLLO Lunar Laser Altimeter provide a solid basis for optimizing the technique for LGO. Existing laser altimetry sensors are simple in design; yet require technological improvements in order to provide comprehensive coverage of the lunar surface. Laser lifetime, efficiency, and pulse repetition-rate are the key factors. Conventional solid-state, pulsed laser technology is restricted by flashlamp lifetime to 10^6 pulses, efficiencies on the order of 1%, and 20 Hz repetition rates. The recent breakthroughs in diode-pumping of Nd:YAG crystal lasers have dramatically improved all three of these factors by orders-of-magnitude. Now we have available diode-pumped Nd:YAG lasers with lifetimes in excess of 10^9 pulses, efficiencies of 10%, and repetition rates of at least 100 Hz. At the same time, this new technology has decreased the size of the laser, eliminated closed-cycle liquid cooling systems, and provided a very robust all solid-state laser package. Efforts are still required to demonstrate the production of nsec-duration pulses with these lasers and then couple the lasers into an altimeter system.

We are constructing a prototype model of the Lunar Observer Laser Altimeter (LOLA) capable of continuously measuring the range to the lunar surface with sub-meter vertical resolution within a 30

- 300 m diameter surface footprint. This same instrument is also designed to provide a direct measure of the surface height distribution in the footprint by waveform analysis of the backscattered laser pulse. Both these measurements are to be made in a continuous, nadir profile across the lunar surface from a 100 km orbit. The wavelength of the altimeter is 1064 nm. A short-pulse (2 nsec), diode-pumped Nd:YAG laser combined with a 25 cm diameter telescope, silicon avalanche photodiode detector, ranging electronics, and instrument computer has been designed to make these measurements and meet all the requirements of the LGO mission. The final LOLA package should weigh less than 15 kg, measure less than 35 cm by 25 cm by 25 cm, and consume an average power of less than 15 watts.

The development of the LOLA prototype is being funded at the \$100K per year level through RTOP Task: 157-30-80 as part of the Planetary Instrument Development Program in Code EL at NASA Headquarters. The LOLA diode-pumped Nd:YAG laser is being funded at the \$500K level at Lightwave Electronics, Inc., Mountain View, California through a Phase II SBIR contract. The completed prototype LOLA instrument will be tested during 1988 from NASA high-altitude aircraft over planetary analog terrain in Arizona, Mexico, and Iceland. The LOLA Project is expected to retain the advantages of a small, self-contained in-house effort throughout the full-scale development of a spacecraft payload.

Project Scientists: James Garvin, Code 622 and Maria Zuber, Code 621. **Project Engineers:** Jack Bufton, Code 674, Maxwell Strange, Code 674, John Dambik, Code 674, and James B. Abshire, Code 723

YAG AEROSOL LIDAR

by

R. Sullivan (674)

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The Global Atmospheric Backscatter Experiment (GLOBE) Mission, using the NASA DC-8 aircraft platform, is designed to provide the magnitude and statistical distribution of atmospheric backscatter cross section at lidar operating wavelengths. This is a fundamental parameter required for the Doppler lidar proposed to be used on a spacecraft platform for global wind field measurements. The prime measurements will be made by a CO₂ lidar instrument in the 9 - 10 um range. These measurements will be complemented with the Goddard YAG Aerosol Lidar (YAL) data in two wavelengths, 0.532 um and 1.06 um, in the visible and near-infrared. The GLOBE experiment will be conducted over the Pacific Basin where there is great interest in the backscatter from clean, remote air masses.

The YAL, being a new activity, is being designed to utilize as much existing hardware, as feasible, to minimize cost and reduce implementation time. The instrument utilizes a 16-inch telescope which is mounted vertically and can be rotated for either an uplooking or a downlooking port. This provides aerosol data acquisition from the nadir position or aerosol data and in-flight calibration data in the zenith position.

The laser, energy monitor, telescope and detector package will be mounted on an optical breadboard. The optical breadboard is mounted through isolation mounts between two low boy racks.

The detector package will utilize a photomultiplier tube for the 0.532 um channel and a silicon avalanche photo detector (APD) for the 1.06 um channel.

The data acquisition system is being developed by using a desk top PC 386 with a CAMAC crate. The data storage will be provided on an optical disk with a tape back-up system. The data acquisition system will be located in a separate electronic rack.

Purchase Orders have been initiated for all major components. Some of the items have been received. Design drawings are in progress for fabrication of mounting hardware for the optics, telescope, energy monitor, and detector package.

Integration of the instrument into the DC-8 and the flight mission is being scheduled for the Spring of 1989.

Project Manager: Robert J. Sullivan (674)

Project Scientist: James D. Spinhirne (617)

Project Engineer: Fredrick G. Huegel (674)

OCEAN COLOR

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Applications of the Coastal Zone Color Scanner
in Oceanography

by

C. R. McClain (671)

Research activities has continued to be focused on the applications of the Coastal Zone Color Scanner (CZCS) imagery in oceanography. A number of regional studies have been completed including investigations of temporal and spatial variability of phytoplankton populations in the South Atlantic Bight, Northwest Spain, Weddell Sea, Bering Sea, Caribbean Sea and in tropical Atlantic Ocean. Also, Frank Muller-Karger who was supported to work at GSFC by the NASA Graduate Researchers Assistantship Program completed his Ph.D. requirements at the University of Maryland. His dissertation research was a study of biological variability in the Caribbean Sea and Eastern tropical Atlantic Ocean.

In addition to the regional studies, much work was dedicated to developing ancillary global scale meteorological and hydrographic data sets to complement the global CZCS processing products (see discussion below). To accomplish this, SEAPAK's image analysis capability was complemented with an interface to GEMPAK (Severe Storm Branch's meteorological analysis software package) for the analysis and graphical display of gridded data fields. Plans are being made to develop a similar interface to SEAPAK for hydrographic data using EPIC (a hydrographic data analysis package developed by NOAA/PMEL). A Director's Discretionary Fund

proposal was approved for the support of a dedicated data programmer/analyst to be located at the NASA Climate Data System (NCDS). He handles the implementation of selected meteorological and hydrographic data sets into NCDS.

Over the last year, a major effort has been the processing of the CZCS data set. This is a collaboration among members of the Oceans and Ice Branch (Code 671), Code 630, and the University of Miami. The Code 671 component has the responsibility of quality control of the final products. Finally, during the last year, plans for a CZCS follow-on mission, SeaWiFS, have progressed to the point where it appears that the mission will be approved for a 1991 launch on LandSat-6.

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OCEAN COLOR OBSERVATIONS OF PHYTOPLANKTON DISTRIBUTIONS
AND PRIMARY PRODUCTIVITY

by

W. Esaias (671)

The primary goal of this activity is to develop the means to assess the mean and variability of phytoplankton biomass and primary productivity on global scales.

There are three major approaches whose goals are to provide global scale observations. These are 1) processing and analysis of the complete CZCS data set in a consistent manner; 2) preparing science mission and project implementation plans for the Sea-WiFS sensor to be launched on Landsat 6 in 1991; and 3) providing guidance to EOS flight projects for ocean color observations using the MODIS sensor planned for the Polar Platform in the mid 1990's.

The analysis of the CZCS data set is being conducted in collaboration with other ocean color investigators here at GSFC and at the University of Miami. This processing presents the first consistent view of phytoplankton pigments on global scales, and analysis of this temporally undersampled data set is proving very instructive in specifying mission requirements for Sea-WiFS and future algorithm development. We have begun an error assessment of the application of simple satellite pigment - primary productivity relationships when used with such observations. This is limited to a zonal analysis to overcome

spatial undersampling on monthly scales. Satellite ocean color algorithm refinement and more rigorous quality assessment, while keeping the relationship between satellite pigment and primary production constant, have increased global estimates of ocean productivity to 62 Gigatons carbon per year, an increase of nearly 20% over estimates derived from initially processed data.

Present relationships between satellite ocean color and in-situ bio-optical processes will be tested further during the JGOFS 1989 Spring Bloom Experiment in the North Atlantic. We are assisting with the required airborne ocean color remote sensing support for this experiment to both provide improved spatial sampling for the ship study as well as to begin development of ocean color algorithms which make use of the improved SeaWiFS sensor bands.

Application of the CZCS and future SeaWiFS data to address scientific questions requires close coordination with a number of non-NASA research programs. We therefore devote a significant fraction of our effort serving on review panels and steering committees. These include the NAS CO2 Panel, the GOF S Science Steering Committee, NSF GOF S Relevancy Review Panels, the Marine Pollution Task Force (also known as the Bradley Committee), the Science and Technology Advisory Committee Remote Sensing Working Group of the Chesapeake Bay Consortium, and the ONR Special Research Initiatives Review Panel.

In coordination with investigators from the Chesapeake Bay

Consortium, we will conduct remote sensing overflights of research and monitoring cruises this summer using the Ocean Data Acquisition System (ODAS) on the Virginia Institute of Marine Science's aircraft. The ODAS, developed under joint NOAA and NASA funding, provides real-time output of chlorophyll pigment and surface temperature to a ship station. If the curvature algorithm which enables the real time computation is found sufficiently accurate for the Bay, the potential for "operational" use of the sensor by CBC will be established.

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Coastal Zone Color Scanner Studies

by

J. Elrod (671)

Activities over the past year have included cooperative work with a summer faculty fellow using the Coastal Zone Color Scanner (CZCS) imagery to study the effects of gradients in trophic resources on coral reefs in the Caribbean. One paper from this project has been submitted for publication and another will be presented at a symposium this summer in Australia. Other research included characterization of ocean radiances specific to an acid-waste plume. Course material for a training course in Bangladesh on satellite oceanography was prepared before the trip was cancelled, due to strikes in that country. However, the course will be presented in June 1988. Other activities include involvement in the quality control of imagery produced in the processing of the global CZCS data set, the collection of various other data global sets, and the subsequent data comparison and analysis.

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Remote Sensing of Ocean Color in the Arctic

by

N. G. Maynard (671)

The main objectives of the research are: 1) to increase the understanding of biological production (and carbon fluxes) along the ice edge, in frontal regions, and in open water areas of the Arctic and the physical factors controlling that production through the use of satellite and aircraft remote sensing techniques; and 2) to develop relationships between measured radiances from the Multichannel Aircraft Radiometer System (MARS) and the bio-optical properties of the water in the Arctic and adjacent seas. Several recent Coastal Zone Color Scanner (CZCS) studies in the Arctic have shown that, despite constraints imposed by cloud cover, satellite ocean color is a useful means of studying mesoscale physical and biological oceanographic phenomena at high latitudes. The imagery has provided detailed information on ice edge and frontal processes such as spring breakup and retreat of the ice edge, influence of ice on ice effects of stratification on phytoplankton production, river sediment transport, effects of spring runoff, water mass boundaries, circulation patterns, and eddy formation in Icelandic waters and in the Greenland, Barents, Norwegian, and Bering Seas.

During the past year, a number of images in the Iceland region and in the Greenland Sea have been processed on both the SEAPACK and Miami systems. These are part of studies on spring blooming

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in Icelandic waters in 1979, 1980, and 1981, the West Spitsbergen Current system, and ice edge phytoplankton dynamics in the Greenland Sea ice edge. Also in 1987/1988, the MARS sensor was completed at the Visibility Lab of Scripps Institution of Oceanography (SIO) and deployed during the Greenland Sea Experiment in May 1987, making eight successful flights over the Polar and Arctic Fronts including overflights of the German icebreaking research vessel, the POLARSTERN. Algorithms are being developed by J. Mueller at SIO and San Diego State University (SDSU). Data is presently being analyzed and will be shared with other participants in the Greenland Sea Experiment from the Alfred Wegener Institute, SIO, SDSU, University of Tennessee, Lamont Doherty Geological Observatory, and other NASA colleagues who participated in coincident overflight in the NASA P-3.

Future plans are to continue to use a combination of historical CZCS data and aircraft observations from high latitude study areas to help build a long-term data base on the Arctic and Antarctic, as well as, to serve as a guide in the selection of optimum sampling strategies in upcoming experiments such as GOFs and CEAREX. The MARS sensor is scheduled to participate in the 1989 CEAREX field season to find and investigate eddies in the Greenland Sea.

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AIRBORNE IN-SITU SPECTRAL CHARACTERIZATION AND CONCENTRATION
 ESTIMATES OF FLUORESCENT ORGANICS AS A FUNCTION OF DEPTH

by

R. A. Tittle (672)

The primary purpose of many in-situ airborne light scattering experiments in natural waters is to spectrally characterize the subsurface fluorescent organics and estimate their relative concentrations. This is often done by shining a laser beam into the water and monitoring its subsurface return signal. To do this with the proper interpretation, depth must be taken into account. If one disregards depth dependence when taking such estimates, both their spectral characteristics and their concentrations estimates can be rather ambiguous.

Figure 1 is a sketch of a simple airborne lidar configuration that will detect the subsurface return signal $E(Z, \lambda)$ from a particular depth Z at the wavelength λ . While the configuration remains unchanged, the depth Z is varied by simply varying the height h of the aircraft. Note that by inspection, we see that

$$Z = [S - h \cdot (\tan A_a - \tan B_a)] / (\tan A_w - \tan B_w).$$

Now with some algebra, we will find

$$K(Z, \lambda_L) \cdot \sec B_w + K(Z, \lambda_f) \cdot \sec A_w = \frac{1}{\Delta Z} \ln \frac{(Z - \Delta Z)^2}{Z^2} \cdot \frac{E(Z - \Delta Z, \lambda_f)}{E(Z, \lambda_f)}$$

where $K(Z, \lambda_1)$ is the diffuse attenuation coefficient at the depth Z and the laser wavelength λ_1 , and where $K(Z, \lambda_f)$ is the diffuse attenuation coefficient at the depth Z and fluorescent

wavelength g_f . Both of these coefficients can be easily calculated.

Now it is well-known that the diffuse attenuation coefficient can be expressed as

$$K(Z, g) = C(z) \cdot f(g)$$

where $C(z)$ is the fluorescent organic concentration as a function of z , and $f(g)$ is the unique proportionality factor, which is equal to the absorptivity when very little scattering is involved, as a function of g . Hence, one easily sees that if we profile $K(z, g)$ as z varies, by analogy, we profile the concentration $C(z)$ as a function of depth.

It should be noted that the monitored collimated return signal beam width must be small compared to Z or else the measurements lose their meanings.

Underwater scatterometer have been employed to show that in-situ subsurface organics are very sensitive to depth, but they also require the use of slow moving boats to cover large sample areas. Also, their very entry into the water disturbs the sample it is measuring. The method described above is superior to any employed thus far. It is the simplest of any employed thus far. It will provide accurate characteristic measurements of the return signal $E(z, g)$ as a function of depth z and wavelength g . It will also provide accurate measurements of the relative concentration as a function depth.

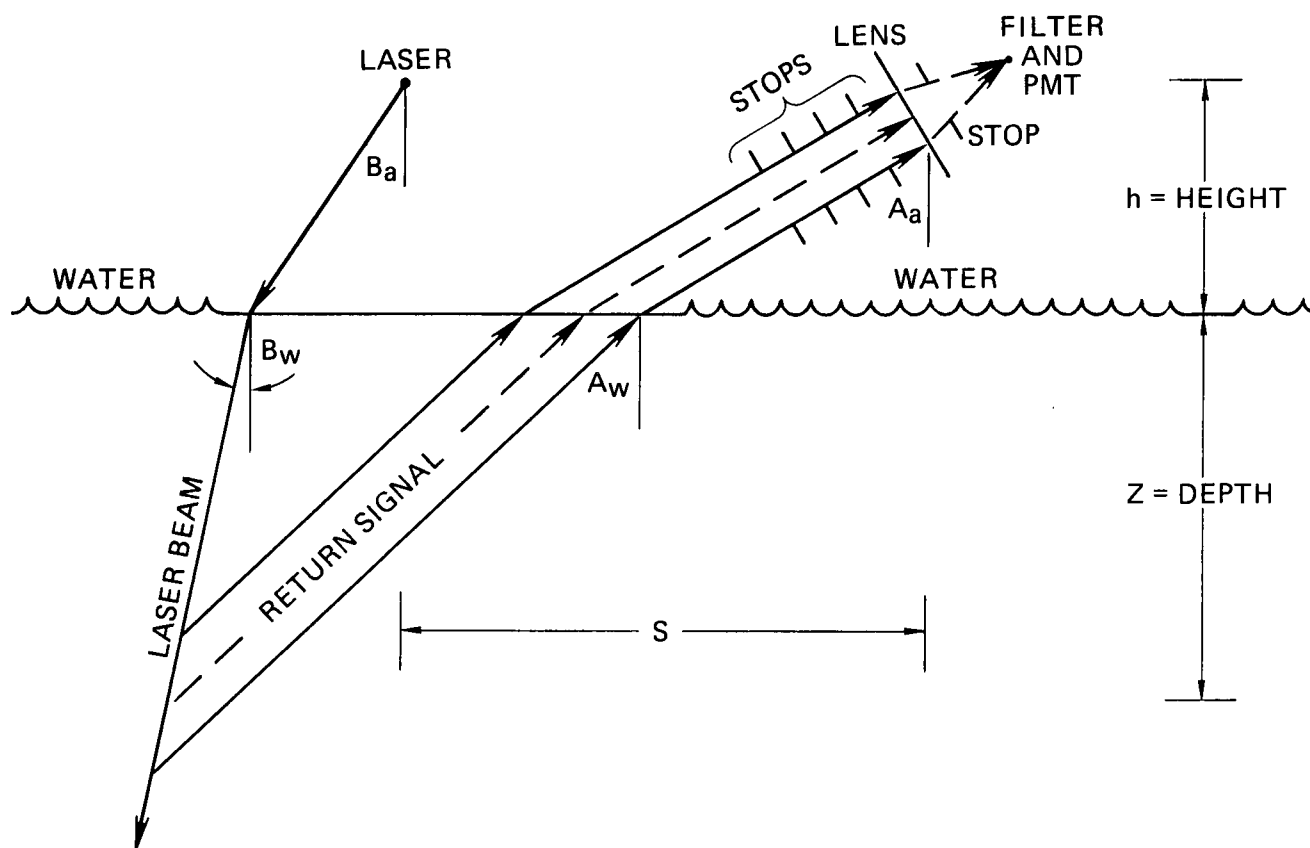


FIGURE 1

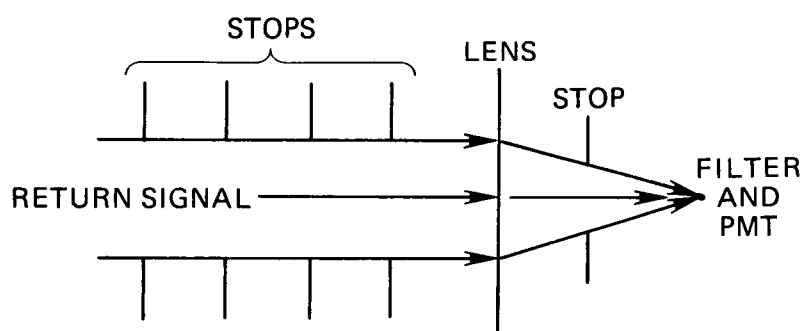


FIGURE 2

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OCEANOGRAPHIC APPLICATIONS OF LASER TECHNOLOGY

by

F. E. Hoge (672)

Oceanographic activities with the AOL for the past several years have primarily been focussed on using active (laser induced pigment fluorescence) and concurrent passive ocean color spectra to improve existing ocean color algorithms for estimating primary production in the world's oceans. The most significant results in this research thrust have been the development of a technique for selecting optimal passive wavelengths for recovering phytoplankton photopigment concentration and the application of this technique, termed active-passive correlation spectroscopy (APCS), to various forms of passive ocean color algorithms. Included in this activity is use of airborne laser and passive ocean color for development of advanced satellite ocean color sensors.

The field missions used to gather the active-passive ocean color spectra essential to this research are conducted as part of large, multi-institutional, oceanographic field studies. These past (and some ongoing) field programs involve numerous government agencies, universities, and oceanographic institutions. These studies involve the cooperative exchange of AOL and shipboard data and information. This exchange of data has been mutually beneficial, providing ship truthing observations essential to the interpretation of the airborne

remote sensing chlorophyll and phycoerythrin pigment fluorescence data, while furnishing oceanographers on board the ships with wide area, nearly synoptic information about the regional distribution of the phytoplankton pigments and temperature information gathered with the AOL.

Airborne laser-induced chlorophyll and phycoerythrin fluorescence data are supplied to cooperating investigators shortly after the conduct of the field experiments. Corroboration with participating scientists in the analysis of the data and publication of important findings is an ongoing activity.

Promising on-wavelength subsurface scattering layer measurements were recently obtained and have been submitted for publication. A partial summary of these results are shown in figure 1a. The submerged marine scattering layer field experiment was conducted in the Atlantic Ocean southeast of Assateague Island, Virginia. NASA's AOL was operated in the bathymetric mode to acquire depth-resolved on-wavelength (532 nm) backscatter signals from shelf/slope waters. Unwanted laser pulse reflection from the air-water interface was minimized by spatial filtering. The presence of thermal stratification over the shelf was verified by the deployment of airborne expendable bathythermographs. Optical beam transmission measurements acquired from a surface truthing vessel indicated the presence of a layer of turbid water near the sea floor over the inner portion of the shelf. These results indicate the ultimate potential for making depth-resolved

chlorophyll concentration measurements. These measurements would involve the use of a second laser operating in the blue spectral region.

It has been shown that significant potential exists for the satellite detection of the accessory pigment phycoerythrin using recently developed APCS techniques. During the past several years, the symmetric three-band (460, 490, 520 nm) spectral curvature algorithm (SCA) has demonstrated rather accurate determination of chlorophyll pigment concentration using low-altitude airborne ocean color data. It has recently been shown that the in-water asymmetric SCA, when applied to certain recently proposed OCI (NOAA-K and SPOT-3) and OCM (ERS-1) satellite ocean color bands, can adequately recover chlorophyll-like pigments. These airborne findings suggest that the proposed new ocean color sensor bands are, in general, satisfactorily but not necessarily optimally, positioned to allow space evaluation of the SCA using high precision, atmospherically corrected, satellite radiances. This analysis indicated that pigment concentration recovery was not as good when existing Coastal Zone Color Scanner bands were used in the SCA. The in-water asymmetric SCA chlorophyll pigment recovery evaluations were performed using: (a) airborne laser-induced chlorophyll fluorescence, and (b) concurrent passive upwelled radiances. Data from a separate ocean color sensor aboard the aircraft were further used to validate these findings. Global satellite detection and mapping of phycoerythrin could lead to better primary production

estimates and improved understanding of phytoplankton species variability. A sample of the application of the APCS methodology to airborne data for the passive detection of phycoerythrin is shown in figure 1b.

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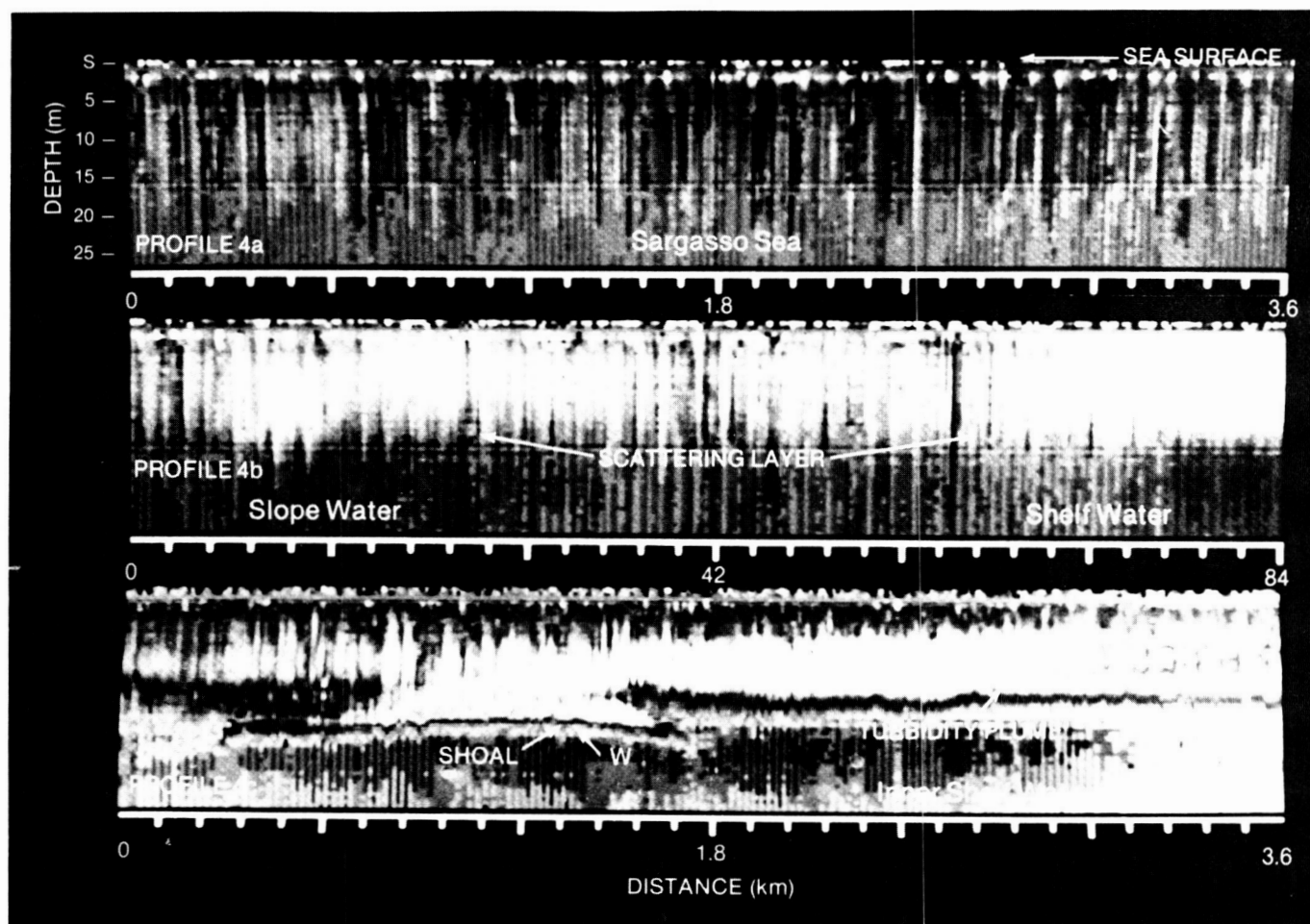


Figure 1a. On-wavelength 532nm laser backscatter profiles obtained from beneath the Atlantic Ocean surface southeast of Wallops Island, Virginia. Specifically, depth-resolved particulate backscatter was observed in shelf/slope and in inner-shelf waters.

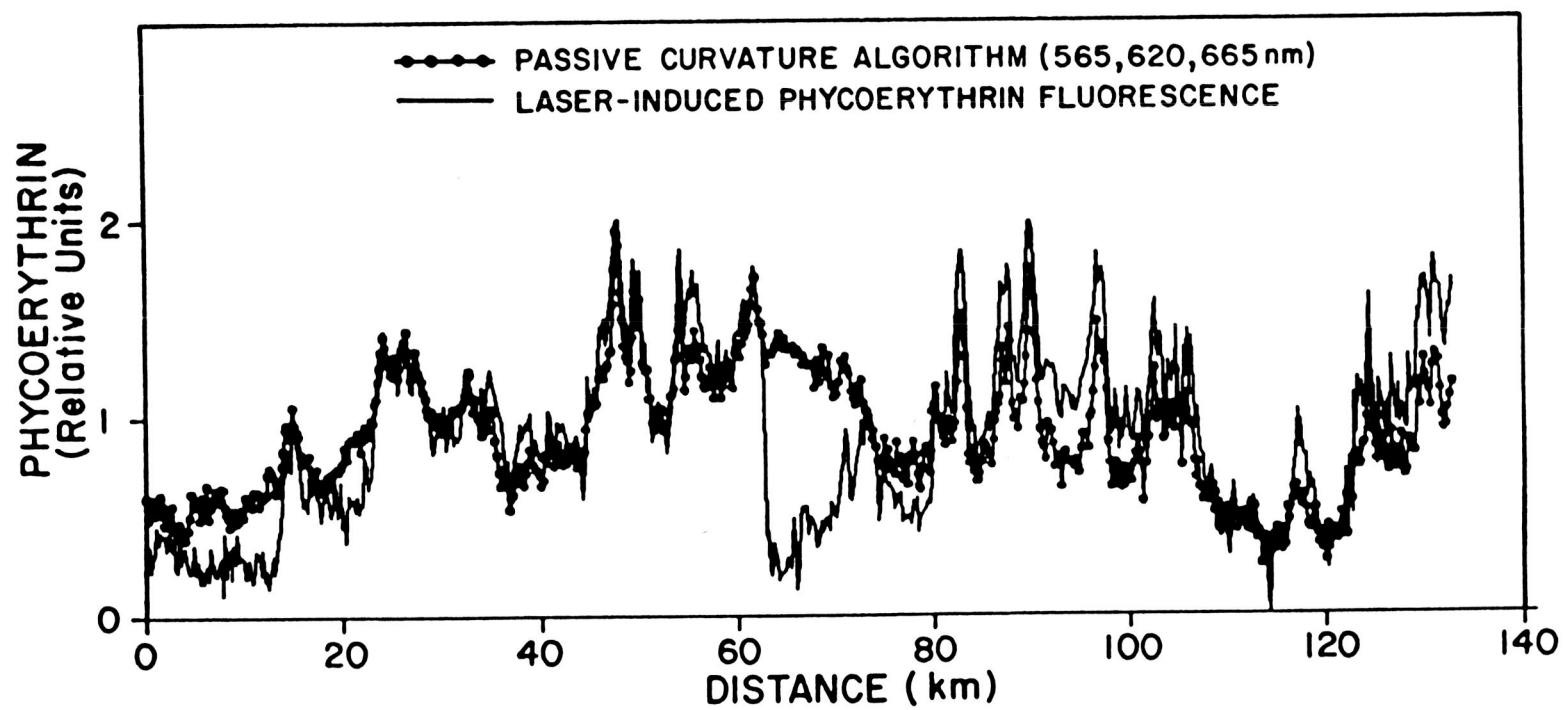


Figure 1b.

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NASA CHARGE COUPLED DEVICE (CCD) SPECTROMETER SYSTEM (NCSS)

by

C. W. Wright, S. A. Bailey (672), and C. R. Piazza (CSC)

A small lightweight NCSS has been designed, constructed, and is now being bench tested at Wallops. The unit provides 256, 2.7 nanometer wide channels in the visible spectrum from approximately 400 to 1100 nanometers. The present input slit provides a spectral impulse response of about 10 nanometers. Up to five NCSS sensors may be bused to one data system interface. This bus interface allows near-simultaneous data capture from those sensors.

The NCSS can output Spectra at a maximum rate of 400 per second. The acquired signal amplitude is inversely proportional to the read-out rate. The time-between-spectra is the integration time. This is the time allowed for a charge to build on each CCD element. Longer intervals between spectra yield greater signal and background amplitudes. Roughly one-third of a second integration (three hertz read-out) is typically used over water targets. The host data system controls the integration time.

The NCSS contains a high speed, 16 bit analog to digital converter (ADC) with an integral wide-band sample-and-hold amplifier. The CCD sensor array, signal amplifiers, and the ADC input are located in close proximity to minimize ground loop and EMI noise. A Z80 microcomputer functions as a programmable state generator which controls the CCD sensor array, the ADC, the data

output registers, and data transmission to the host data system. The new programmable state generator and ADC combination allow new and different CCD sensor arrays to be interfaced with minimum engineering.

The NCSS was developed primarily for use with the Airborne Oceanographic Lidar (AOL). A prototype NCSS is presently interfaced to the AOL. This prototype is constructed from an extensively modified Spectron Engineering SE590 CCD spectrometer head.

The AOL will use two new NCSS units onboard the Goddard P-3a aircraft. They will provide the AOL with high resolution sky and ocean spectra. The up-looking NCSS will provide the AOL data system (AOLDS) with down-welling solar radiance, and the down-looking NCSS will provide ocean color spectra. The solar radiance will be used to correct various ocean color algorithms now being researched.

The NCSS is now interfaced to the AOLDS via a specialized parallel high speed Direct-Memory-Access System Expansion Bus interface. We plan to interface the NCSS to the IBM-PC/AT bus in the near future. The PC interface will allow a small portable lightweight ocean/land color data system.

The NCSS optics consist of: 1) a 1.5cm diameter input lens, 2) an entry slit, and 3) a single 2 x 2 cm reflective diffraction grating. The sensor and electronics consists of a Reticon RL-256 CCD linear array detector digitized by a Analogic 826 ADC.

The CCD and the digitizer are controlled by a Z80 microprocessor.

For further information on the NCSS contact Wayne Wright at the GSFC/Wallops Flight Facility.

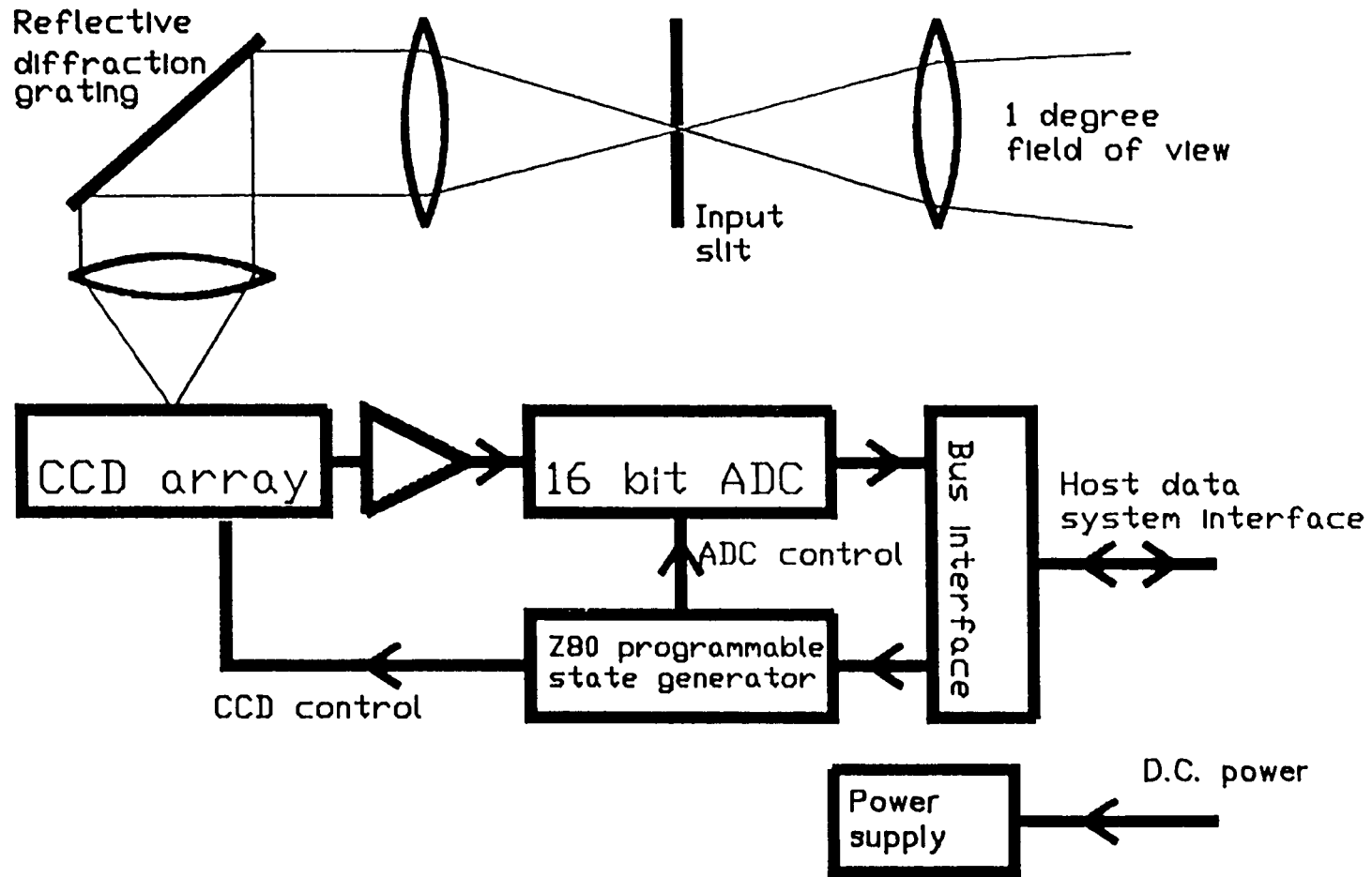


Figure 1. Block Diagram NCSS

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AIRBORNE OCEANOGRAPHIC LIDAR (AOL) FLIGHT MISSION PARTICIPATION

by

F. E. Hoge (672)

During this reporting period of February 1986 to the present, the AOL participated in six interagency flight missions. These were:

(1) Shelf Edge Exchange Processes (SEEP II) (Department of Energy). The SEEP II flight experiments were conducted on shelf and slope waters east of the Delmarva Peninsula during March and April 1988. The SEEP experiments are designed to assess the assimilative capacity of the Continental Shelf to absorb the energy by-products introduced into the near-shore ocean environment from coastal communities and marine activities such as energy production plants and offshore oil operations. During 1985, the AOL had participated in the SEEP I flight missions conducted in the New York Bight.

(2) BIOWATT II (Office of Naval Research). The BIOWATT II flights were conducted in a section of the Sargasso Sea east of Cape Hatteras. The major objective of this study was to provide a better understanding of the relationships between ocean physics, biology, bioluminescence, and optics in oligotrophic portions of the Atlantic Ocean. During 1985, the AOL had participated in the BIOWATT I flight missions conducted in the Sargasso Sea south and west of Bermuda.

(3) Fall Experiment (FLEX) (Department of Energy). The FLEX missions were conducted over shelf and Gulf Stream waters between

Charleston, South Carolina, and Cape Canaveral, Florida. The FLEX studies were designed to determine the fate of low salinity water in the coastal boundary zone that is advected south towards the Florida coast during autumn. During 1985, the AOL had participated in the Spring Experiment (SPREX).

(4) Greenland Sea and Icelandic Marine Biological Experiments (NASA). These flights were conducted in conjunction with the NASA Arctic Ice Experiment. The investigations were designed to evaluate the distribution of surface layer chlorophyll in the Greenland Sea and in the coastal waters in the vicinity of Iceland.

(5) Submerged Oceanic Scattering Layer Experiment (Naval Ocean Systems Center). These flights were conducted over shelf, slope, Gulf Stream, and Sargasso Sea watermasses during June 1986. This flight experiment demonstrated for the first time the feasibility of detecting and metrically measuring the depth to submerged layers of particulate matter in the shelf break region and in the inner coastal zone.

(6) Microbial Exchanges and Coupling in Coastal Atlantic Systems (National Science Foundation). These flight investigations were conducted in shelf and slope watermasses east of Cape Henry, Virginia, during May 1986. This investigation was designed to study the transportation and fate of particulates in coastal waters and in particular the Chesapeake Bay/coastal Atlantic Ocean.

Shortly after the conduct of the flight experiments, airborne laser-induced chlorophyll a and phycoerythrin fluorescence data, as well as sea surface temperature and airborne expendable bathythermograph water column temperature profiles are supplied to cooperating institutions. Corroboration with participating scientists in the analysis of the data and publication of important findings are ongoing activities. During the past several years, numerous papers have been published on oceanic lidar applications to airborne measurement of chlorophyll, phycoerythrin, tracer dye concentration, oil film thickness and identification, monomolecular films, front mapping, water depth, and sea surface backscatter characteristics. Several papers have been recently published on active-passive (laser-solar) airborne ocean color methods for phytoplankton pigment concentration measurement, chlorophyll algorithm development, and general ocean color spectral variability studies.

Future plans call for AOL participation in the North Atlantic Spring Bloom Process Study of the Joint Global Ocean Flux Study. This multi-nation experiment is designed to improve the understanding of the spring bloom development in the open ocean. Research ships from Great Britain, Germany, The Netherlands, and the U.S. will conduct sampling along the 20 W transect in the Spring of 1989. It is anticipated that the AOL will conduct its overflights from both Iceland and Ireland.

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OCEAN DATA ACQUISITION SYSTEM

by

B. Johnson, J. Cavanaugh, J. Smith (674), W. Esaias (671)

The Ocean Data Acquisition System (ODAS) is a low-cost instrument with potential commercial application. It is easily mounted on a small aircraft and flown over the coastal zone ocean to remotely measure sea surface temperature and three channels of ocean color information. From this data, chlorophyll levels can be derived for use by ocean scientists, fisheries, and environmental offices. Data can be transmitted to shipboard for real-time use with sea truth measurements, ocean productivity estimates and fishing fleet direction.

The aircraft portion of the system has two primary instruments: an IR radiometer to measure sea surface temperature and a three channel visible spectro-radiometer for 460, 490, and 520 nm wavelength measurements from which chlorophyll concentration can be derived. The outputs of both instruments is fed into a data system where they are digitized to 12-bit resolution, formatted, recorded on-board, and transmitted to a receiving (shipboard) system for processing. The aircraft package contains a LORAN-C unit for aircraft location information, clock, on-board data processor and formatter, digital data storage, packet radio terminal controller, and radio transceiver for data transmission to a ship. From the measurement altitude of 500 feet, the line of sight transmitter range to a ship is about 30 miles. The VHF transceiver can also be used for voice communication and

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coordination between aircraft and ship.

The shipboard package contains a transceiver, packet terminal controller, data processing and storage capability, and printer. Both raw data and chlorophyll concentrations are available for real-time analysis.

To keep down the cost of reproducing the instrument system in the future, commercially available subsystem components are principally used. Good quality camera lenses for the optical systems, amateur radio packet controllers, and modified amateur transceivers (modified to FCC assigned ODAS frequencies) for the data transmission systems, and rack mountable personal computers for the data systems are examples.

FIELD MISSIONS:

ENGINEERING FLIGHTS AT WALLOPS FLIGHT FACILITY; MAY 13, 1987
1987 AIRBORNE SCIENCE EXPEDITION TO THE ARCTIC OCEAN NEAR
SPITSBERGEN; MAY 17 - MAY 30, 1987.
BIOWATT FALL EXPEDITION, NOVEMBER 1987
SEEP II (SHELF EDGE EXCHANGE PROGRAM); MARCH 1988.

1. MEASUREMENT TECHNIQUE: NARROW BAND INTERFERENCE FILTERS AND SILICON DETECTORS.
2. OBSERVATION WAVELENGTH(S): 460, 490, & 520 nm.
3. PARAMETER MEASURED: OCEAN COLOR TO DERIVE CHLOROPHYLL.
4. SENSOR HEAD SIZE: 12" DIAM. X 17" DEEP WEIGHT: 25 POUNDS (EST)
5. DATA SYSTEM: 19"W X 15"D X 9"H (AIRBORNE DATA SYSTEM IS A PERSONAL COMPUTER W/ PLUG-IN A/D CONVERTER & "HARD CARD".
SHIPBOARD DATA SYSTEM IS A PERSONAL COMPUTER WITH HARD DISC OR CARD. WEIGHT: 30 POUNDS (EST) DATA RATE (BPS): 1200
6. REMOTE SENSING AIRCRAFT USED: WFF P-3 DE HAVILLAND "BEAVER".

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COASTAL ZONE COLOR SCANNER

by

B. Johnson (674)

The Coastal Zone Color Scanner (CZCS) spacecraft ocean color instrument is capable of measuring and mapping global ocean-surface chlorophyll concentration. It is a scanning radiometer with multiband capability. It operated successfully for 7 years on Nimbus VII. The engineering model of CZCS underwent extensive functional testing and some environmental testing during the development of the flight instrument at the contractor, Ball Brothers. The engineering model is presently in a Code 674 laboratory. With new electronics and some mechanical, and optical re-work, it probably can be made "flight worthy." Some additional components of a second flight model are also available. An engineering study and further tests are necessary to determine exactly what effort is required to properly prepare the instrument for spaceflight and the nature of interfaces to prospective spacecraft (e.g., AEM, BSS, Eos Polar Platform). The following is an outline of a proposed preliminary study by our branch to assess the value of further pursuing a spaceflight opportunity for this instrument. We estimate that this in-house study could be completed in 12 months at a cost of about \$25K.

1. Goal
 - 1.1. Instrument Status
 - 1.2. Rework Feasibility
2. Science & Applications
 - 2.1. Global Ocean Color
 - 2.2. Ocean Productivity & Currents
 - 2.3. Global Biogeochemical Cycles (e.g., CARBON)

- 2.4. Commercial & Operational Uses
- 2.5. Value-Added Industry
- 3. Engineering Model Status
 - 3.1. Flt Model History: 7 Yrs Lifetime
 - 3.2. E/M Previously Tested
 - 3.3. E/M Available
 - 3.4. Appears Good Condition
- 4. Study & Test Effort
 - 4.1. Optical
 - 4.1.1. Alignment Verification
 - 4.1.2. Spectral Characteristics
 - 4.1.3. IFOV
 - 4.1.4. Detector Sensitivity
 - 4.1.5. Spectral Characteristics
 - 4.2. Mechanical
 - 4.2.1. Fit on Small Satellite (E.G. AEM, BSS)
 - 4.2.2. Requirements & Mods to Fly on Scout
 - 4.2.3. Environmental Considerations
 - 4.2.4. Materials
 - 4.3. Electronic
 - 4.3.1. Evaluate/update Scan Motor Drive Circuit
 - 4.3.2. Evaluate/update Signal Analog Circuits
 - 4.3. Define Instrument Parameters (Characteristics SPECS)
 - 4.4. R&QA Rationale (e.g., OCE STRATEGY)
- 5. Cost
 - 5.1. Contractor Mechanical Engineer & Technician
 - 5.2. "Breadboard" Parts; Mechanical & Electronic
- 6. Milestones
 - 6.1. Review & Document Test & Study Results
 - 6.2. Document Recommendations

The CZCS provides operational instrument capability for monitoring of ocean productivity and currents. It could be a simple, low cost alternative to developing new instruments for ocean color imaging. Researchers have determined that with global ocean color data they can: specify quantitatively the role of oceans in the global carbon cycle and other major biogeochemical cycles; determine the magnitude and variability of annual primary production by marine phytoplankton on a global

scale; understand the fate of fluvial nutrients and their possible affect on carbon budgets; elucidate the coupling mechanism between upwelling and large-scale patterns in ocean basins; answer questions concerning the large-scale distribution and timing of spring blooms in the global ocean; acquire a better understanding of the processes associated with mixing along the edge of eddies, coastal currents, western boundary currents, etc., and acquire global data on marine optical properties¹.

The technique for processing and archiving the data from the CZCS instrument would utilize the CZCS global data processing and archiving system existing at GSFC. Existing algorithms would be used.

¹System Concept for Wide-Field-Of-View Observations of Ocean Phenomena from Space, August 1987.

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THE MULTICHANNEL OCEAN COLOR SENSOR (MOCS)

by

J. D. Oberholtzer and C. R. Vaughn (672)

The MOCS is an imaging spectroradiometer with a sensitivity that matches the light upwelling from open bodies of water. Twenty contiguous spectral channels in the visible are recorded in a line scanning mode from an aircraft. The system also supports a thermal infrared radiometer and will accept input from a position location system.

The sensor in the MOCS system is an image dissector tube. A line from the scene below the aircraft is disbursed onto the face of the image dissector through a grating. This is recorded as a 150 pixel line with 20 spectral channels in each pixel, where the spatial extent is 2 by 4 mrad, and the spectral width of each channel is about 15 nm. Three scans (or lines) are recorded each second; thus, unless the aircraft is quite high, the scene below is sampled rather than recorded as a complete image. For most ocean color missions, this is a reasonable method of collecting data.

Originally at the NASA Langley Research Center, the spectral curvature algorithm was developed during this time. This relates the irradiance in Channel 7 of the MOCS normalized by the channels on either side to the chlorophyll concentration in the water. Channel 7 is centered at 490 nm which is at a chlorophyll absorption peak. No atmospheric correction to the data is needed

for low flying aircraft gathering chlorophyll data using this algorithm.

Although the MOCS is now about 15 years old, because its response has been so stable, we decided to upgrade its data recording system from an obsolete computer with a restricted data record. We chose to duplicate the system used by the Aircraft Oceanographic Lidar where possible. The new MOCS system was designed, and while most of the parts were acquired, the cost of the total system was more than the available funds. To complete the instrument in order to demonstrate the new system, the missing pieces were borrowed from other projects. This was flown on several BIOWATT II missions in 1987 on which data were collected, and the system was shown to work. Earlier, the older data recording system was used in a mission to support the National Science Foundation funded Microbial Exchanges and Coupling in Coastal Atlantic Systems project at the mouth of the Chesapeake Bay. A report of this mission is in preparation.

There have been no funds to finish the data recording system; however, a proposal to NASA Headquarters for the necessary funds will be submitted.

The MOCS has been a reliable instrument for recording ocean color from low flying aircraft. As NASA enters the next period of ocean color investigations from space, such a device can play an important role in calibration of the space instrument, as well as provide support for programs developing the next generation of space borne devices.

SEA ICE

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ARCTIC SEA ICE STUDIES WITH
PASSIVE MICROWAVE SATELLITE OBSERVATIONS

by

D. J. Cavalieri (671)

The objectives of this research are: (1) to improve sea ice concentration determinations from passive microwave space observations; (2) to study the role of Arctic polynyas in the production of sea ice and the associated salinization of Arctic shelf water; and (3) to study large-scale sea ice variability in the polar oceans. The strategy is to analyze existing data sets and data acquired from both the DMSP SSM/I and recently completed aircraft underflights. Special attention will be given the high resolution 85.5 GHz SSM/I channels for application to thin ice algorithms and processes studies.

A study relating the fluctuations in the sea ice areas of the Bering and Okhotsk seas to changes in the position and intensity of quasi-stationary high and low pressure systems associated with large-scale standing wave patterns in the atmosphere has been completed and published (Cavalieri and Parkinson, 1987). Other work recently completed include a comparison of SIR-B and SMMR Weddell Sea ice concentrations (Martin, et al., 1987) and a study of how ice surface conditions, imaging geometry and choice of algorithm parameters affect the computation of sea ice concentrations using both active and passive microwave sensors (Burns, et al., 1987). Most recently,

and as part of the NASA DMSP SSM/I Sea Ice and Snow Validation Program, a series of coordinated aircraft SSM/I underflights with three aircraft were completed in March 1988. NASA's DC-8 airborne laboratory carried both active and passive microwave sensors. The DC-8 radiometers with frequencies and polarizations that closely match those of the SSM/I were developed and operated by Goddard's Microwave Sensors and Data Communication Branch under the direction of Dr. T. T. Wilheit. The active sensors on the DC-8 included the JPL P-, L-, and C-band SAR. Two Navy research aircrafts also participated in these underflights in support of the NASA program and provided additional passive and active microwave coverage.

Analysis of aircraft and satellite data sets is expected to provide a basis for determining the potential of the SSM/I high frequency channels for improving sea ice algorithms and for investigating oceanic processes. Improved sea ice algorithms will aid the study of Arctic coastal polynyas which in turn will provide a better understanding of the role of these polynyas in maintaining the Arctic watermass structure. Analysis of satellite and archived meteorological data sets will provide improved estimates of annual, seasonal and shorter-term sea ice variability.

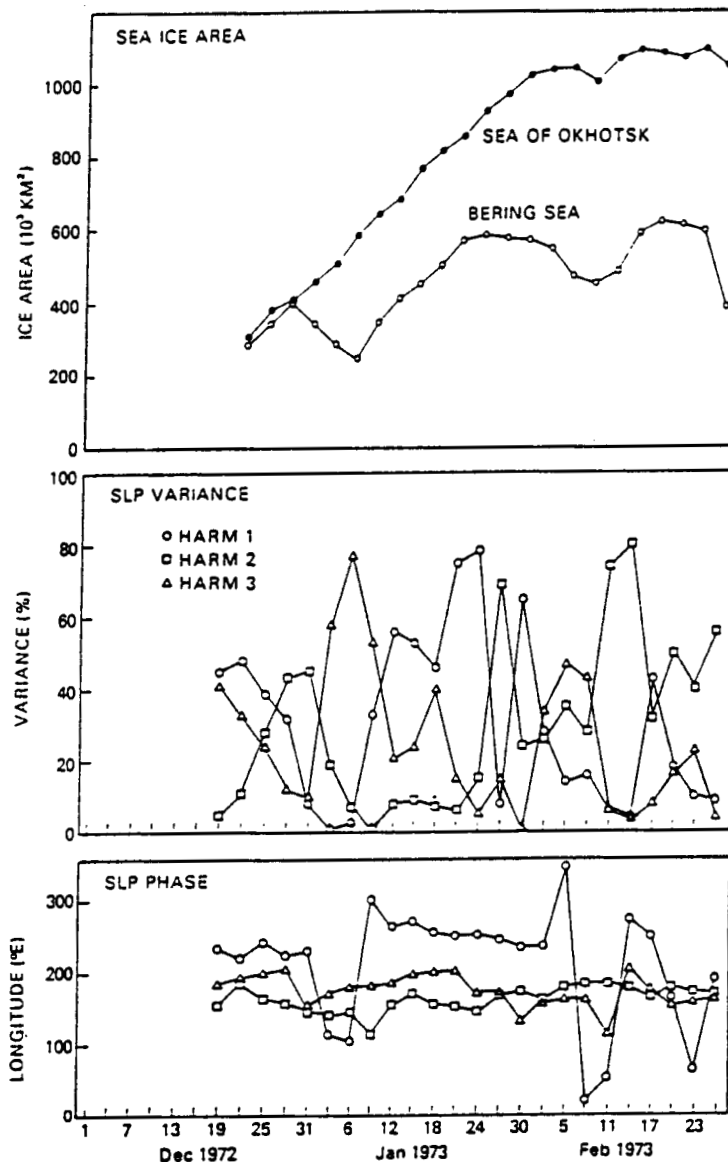


Figure 1. Time series of the sea ice covered areas in the Bering and Okhotsk seas, percent variance, and the longitudinal phases of the first three harmonics of a zonal Fourier analysis of the atmospheric sea level pressure for the Winter of 1972-73. The phase of each harmonic corresponds to the position of minimum amplitude or low pressure. Two midwinter Bering Sea ice retreats starting on December 28 and January 27, respectively, are preceded by a reduction in the variance explained by harmonic one and an increase in the variance explained by harmonics two and three. Rapid changes in the phases of these harmonics are also observed and are associated with changes in the position of both the Aleutian Low and the Siberian High, two wintertime semi-permanent circulation features. The direction of the winds associated with these two systems determine whether the ice advances or retreats these two seas (Cavalieri and Parkinson, 1987).

MICROWAVE REMOTE SENSING OF SEA ICE

by

J. C. Comiso (671)

The long term objectives of this research project are as follows:

a) to understand the physics of the multispectral microwave radiative characteristics of sea ice as it goes through different phases: b) to improve characterization of sea ice cover using satellite microwave sensors: and c) to study ice/ocean physical and biological processes associated with polynya formations and variability of the marginal sea ice region.

Two field experiments have been conducted to pursue these objectives. One involved measurements of radiative and physical characteristics of sea ice from a ship during a 3-month long cruise through the Weddell Sea ice pack during the Austral winter of 1986. The other involved similar measurements from two aircrafts and a submarine over the Central Arctic and Greenland Sea region. The latter was done in collaboration with scientists from Goddard (Codes 672 and 675), JPL, and Scott Polar Research Institute. Both experiments were very successful. Preliminary results have already led to an enhanced understanding of the microwave signatures of pancake ice, nilas, first year ice, multiyear ice and effects of snow cover.

Coastal and deep ocean polynyas and their role in bottom water formation and ocean circulation have been studied using a time series of ice images from SMMR. A recurring Cosmonaut Sea polynya similar in characteristics but much smaller in size than

the large Weddell polynyas in mid-1970's was discovered. A simple model shows that the size of the polynya is a strong factor that keeps it from persisting throughout a winter period.

An unsupervised cluster analysis of Arctic sea ice using SMMR and THIR emissivity and brightness temperature data has been implemented in collaboration with Code 636 personnel. The analysis indicates the existence of several unique and persistent clusters in the Central Arctic region during winter and that the sum of the area of these clusters excluding those of first year ice is about 20% less than minimum ice cover area inferred from a previous summer data. This result is consistent with saline surface for some multiyear ice floes as observed during MIZEZ and suggests that a significant fraction of multiyear ice floes in the Arctic have first year ice signatures.

Current plans include the completion of analysis of the 1986 Weddell Sea data and the 1987 Arctic aircraft/submarine data and correlation of results with those of SMMR and the recently made available SSM/I data. The role of sea ice in the marginal ice zone phytoplankton bloom is also being studied using CZCS data in conjunction with SMMR data and in-situ observations. This is being done in collaboration with scientists from Goddard, University of Tennessee, and University of Southern California. A field program to measure radiative, electrical, and physical characteristics of Weddell Sea Ice is also scheduled to be conducted from June through July 1988 as part of the AMERIEZ project. These measurements will be utilized to further understand radiative characteristics of sea ice data at 85 GHz.

VERTICAL POLARIZATION

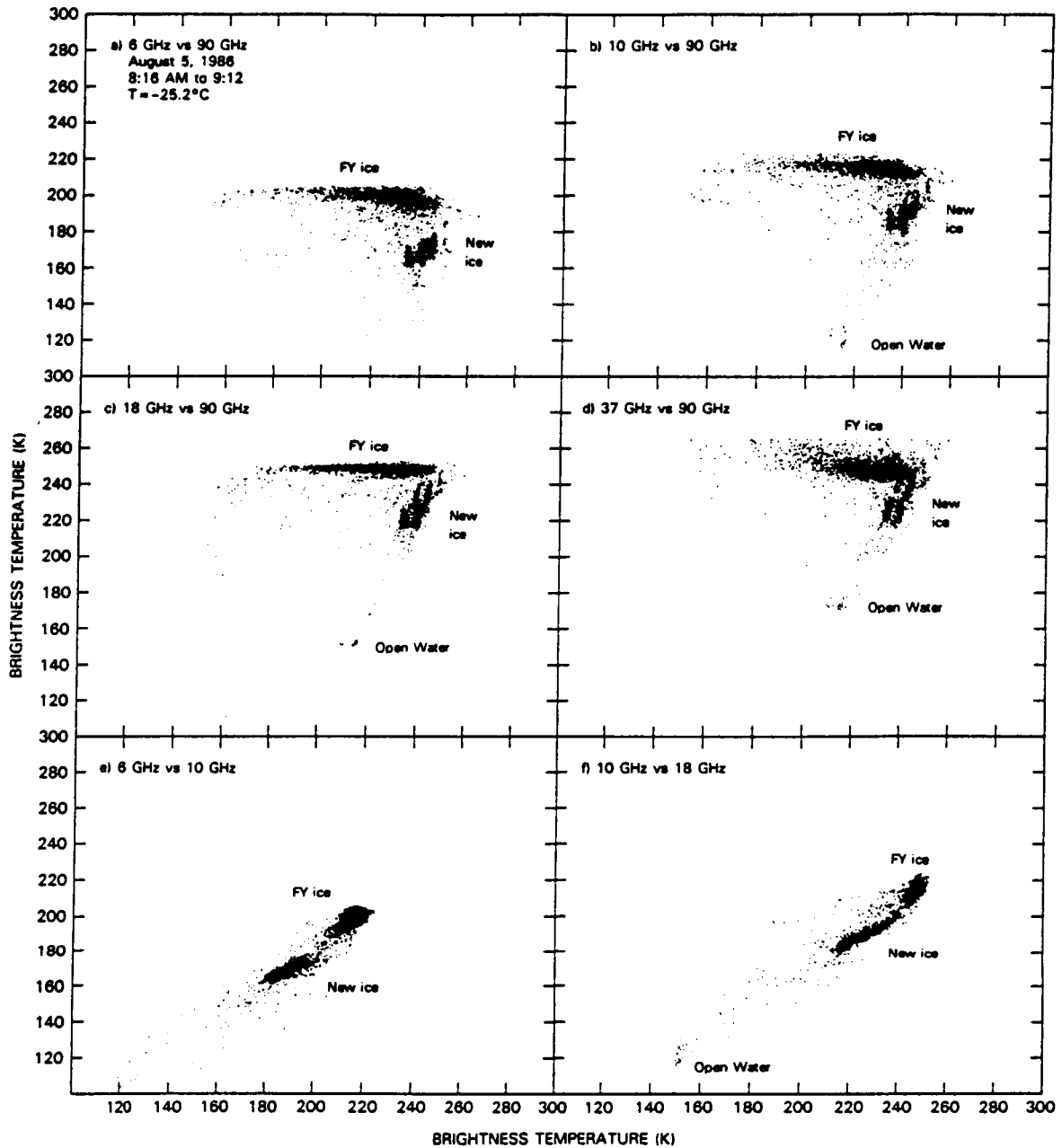


Figure 1. Multispectral passive microwave in-situ observations of Weddell Sea ice cover in Winter of 1986. The series of two-dimensional scatter plots using combinations of different channels at vertical polarization shows ability to discriminate new ice from snow covered and thick first year ice. New Ice from a polynya region are presented by distinct clusters which vary in number and relative position depending on which microwave channels which vary in number and with the 90 GHz channel. Also, the use of a 90 GHz channel with another frequency channel also shows large sensitivity to different state and stages of snow cover in thick first year ice areas.

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ANALYSIS OF SEA ICE DYNAMICS

by

J. Zwally (671)

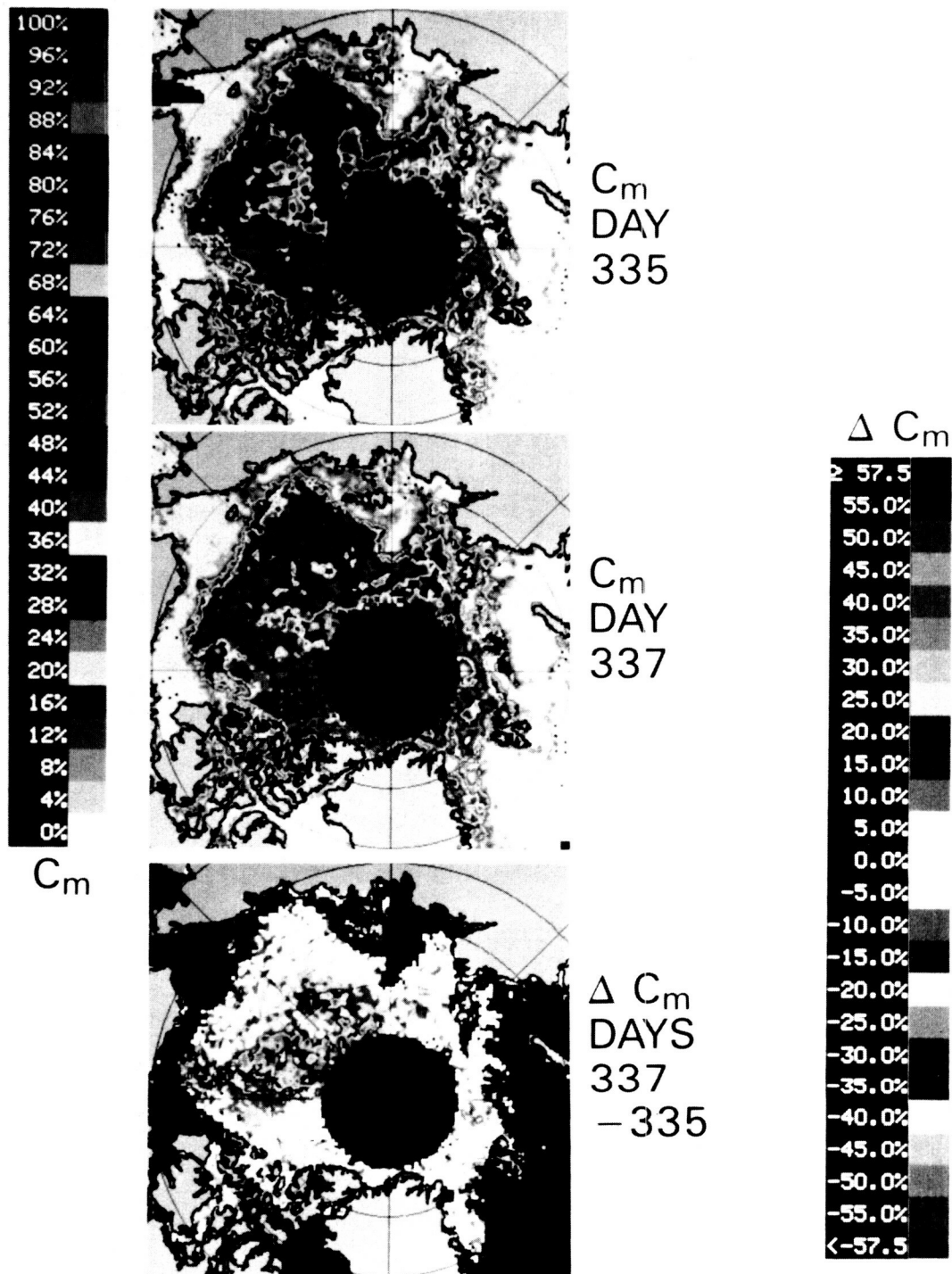
The ongoing work (FY86, FY87, FY88) has established the basis for using multiyear sea ice concentrations from SMMR passive microwave for studies of large-scale advection and convergence/divergence of the Arctic sea ice pack. Comparisons have been made with numerical model simulations and buoy data showing qualitative agreement on daily to interannual time scales. Analysis of the 7-year SMMR data set shows significant interannual variations (15-20%) in the total area of multiyear ice.

The scientific objective is to investigate the dynamics, mass balance, and interannual variability of the Arctic sea ice pack. The research emphasizes 1) the direct application of sea ice parameters derived from passive microwave data (SMMR and SSMI) and 2) collaborative studies with John Walsh using a sea ice dynamics model.

The 7-year time series of multiyear sea cover from SMMR is being analyzed on an interactive computer and compared with Arctic buoy data and sea ice modeling results. SSMI data will be added, as it becomes available, and will be used to examine SMMR/SSMI modifying his version of the Hibler sea ice dynamics model to incorporate the fractional concentrations of multiyear and first

year ice, so that more direct comparisons can be made with the SMMR data.

The possible causes of observed interannual variations in the multiyear ice area are being examined. The relative effects of variations in the large-scale advection and convergence/divergence within the ice pack on a regional and seasonal basis are investigated. The effects of anomalous atmospheric forcings are being examined, including the long-lived effects of synoptic events and monthly variations in the mean geostrophic winds. Estimates to be made will include the amount of new ice production within the ice pack during winter and the amount of ice exported from the pack.



SHORT-TERM MULTIYEAR CONCENTRATION CHANGES

Figure 1. SMMR images of multiyear sea-ice concentration for 30 November (day 335, top) and 2 December (day 337, center) 1980. Field of change of multiyear concentration between 30 November and 2 December is shown at bottom.

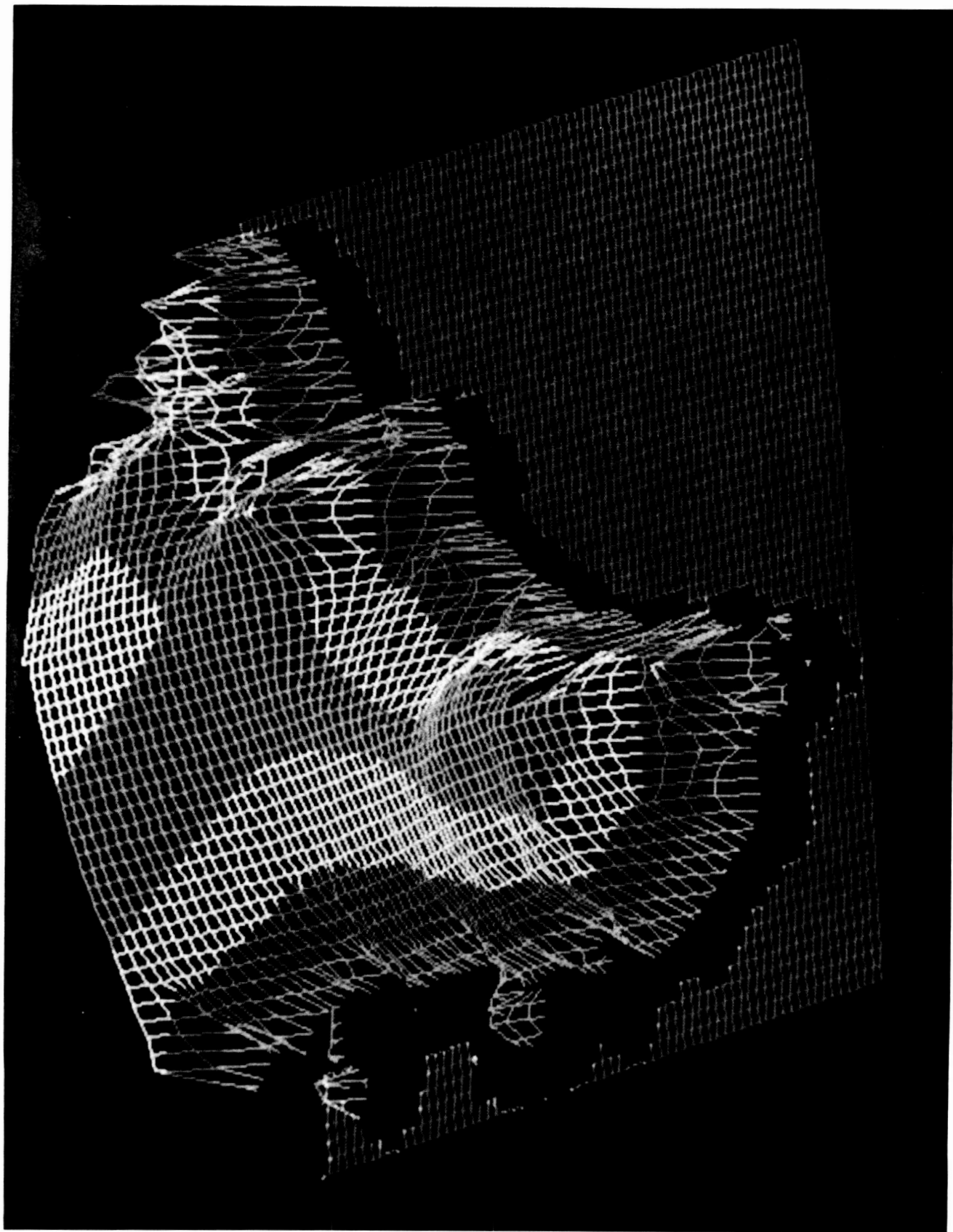


Figure 2. Color Coded Height Contours of the Southern Greenland Ice Sheet.

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ICE SHEET RADAR ALTIMETRY

by

J. Zwally (671)

The surface topography of the Greenland and Antarctic ice sheets between 72 degrees north and south is mapped using radar altimetry data from the U. S. Navy GEOSAT. The glaciological objective of this activity are to study the dynamics of the ice flow, changes in the position of floating ice-shelf fronts, and ultimately to measure temporal changes in ice surface elevation indicative of ice sheet mass balance.

The ongoing activities include extensive processing of the GEOSAT radar altimeter data to obtain corrected ice surface elevations and to produce validated data sets for glaciological research. Data processing techniques have been developed to account for the differences in the operation of radar altimeters over sea ice and the continental ice sheets, as compared to ocean surfaces for which they were designed. In particular, computer retracking is required to correct for the range error caused by lags in the altimeter's automatic tracking circuit that adjusts for changes in the expected range between radar pulses. Each 10/second waveform, representing the received radar signal, is fitted with a five- or nine- parameter function to determine its shape and the position of the mid-point of the ramp with respect to the central range gate, which gives a range correction of typically several meters. Atmospheric and tidal corrections are also applied.

Preliminary elevation maps have been made of Greenland and parts of Antarctica. Crossover analysis shows an overall precision of about 1.6 M with a mean ascending-descending orbit bias of -0.5 M. Procedures have also been developed for editing and smoothing SEASAT data over sea ice, to produce ocean surface maps over the sea ice regions surrounding the ice sheets. These ocean surfaces will be used to reduce the error in the radial component of the satellite orbit and tie the data to a common reference level. Glaciological studies with the data include definition of ice flow directions, the positions of ice divides and drainage basins, the locations of ice rises in Antarctic ice shelves, and other features of ice shelves and ice sheets. Data from Geos-3, SEASAT, and Geosat are being compared to determine whether the ice-sheet surface elevations have changed during the approximately 10-year period of the measurements.

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SEA ICE/CLIMATE STUDIES

by

C. L. Parkinson (671)

The objectives of this work are to determine and analyze the annual cycle of sea ice extents in the Arctic Ocean and peripheral seas and bays over the period 1973-1986, looking in particular for any long-term trends; to examine the relationship between local sea ice covers and the surrounding atmosphere and ocean; and to examine sea ice as a potential early indicator of climate change. The work, which is being done partly in collaboration with D. J. Cavalieri, involves creating regional and hemispheric time series of sea ice variables from satellite passive microwave data and analyzing these through various intercomparisons amongst themselves and with oceanographic and atmospheric fields.

Time series have been generated of monthly averaged sea ice extents from 1979 through 1986 for the Northern Hemisphere and for each of eight subregions, using the data of the Nimbus 7 Scanning Multichannel Microwave Radiometer (SMMR). These 1979-1986 data are being compared with ice extents for 1973-1976 previously calculated from the data of the Nimbus 5 Electrically Scanning Microwave Radiometer (ESMR). Yearly averages and trend lines have also been generated (see figure), as well as plots of the year-to-year changes in each month. There are no strong long-term trends indicated for the Northern Hemisphere as a whole or

for any of the eight subregions. However, although not strong, the trend lines are upward for the Arctic Ocean, Bering Sea, and Baffin Bay/Davis Strait, and are downward for the Sea of Okhotsk, Greenland Sea, and Kara and Barents Seas. The facts that the region with the strongest upward trend, Baffin Bay/Davis Strait, had a decreasing ice extent over the last 3 years of the data set and the region with the strongest downward trend, the Kara and Barents Seas, had an increasing ice cover over the last 2 years (see figure) reemphasize that none of the regions shows a convincing long-term trend.

Because passive microwave technology allows routine monitoring of global sea ice distributions, marked changes in the global sea ice cover can be readily determined. This is not the case for many climate variables and is a characteristic suggesting the potential of sea ice as an early indicator of climate change. However, the natural variability of sea ice is not yet well enough known so that a climate signal could be clearly distinguished from the background noise. This is a central reason for the current research effort to examine sea ice variability, an effort which is covering regional, seasonal, and interannual variations.

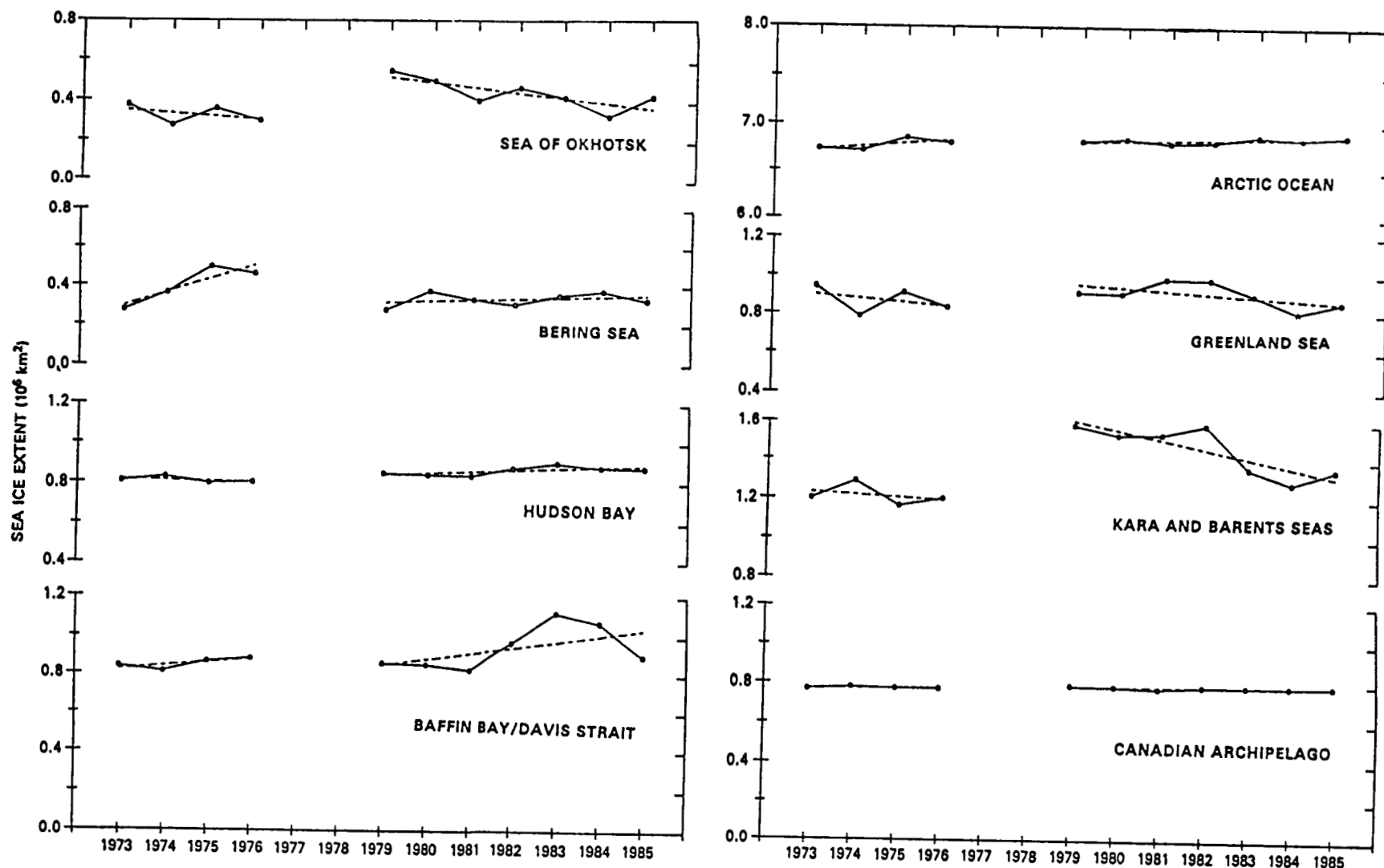


Figure 1. Time series of yearly averaged sea ice extent for each of eight regions in the Northern Hemisphere polar waters, along with lines of least-squares fit. The values for 1973-1976 derive from the data of the Nimbus-5 ESMR, whereas the values for 1979-1985 derive from the data of the Nimbus-7 SMMR.

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ICE SHEET STUDIES USING SYNTHETIC APERTURE RADAR

by

R. Bindschadler (671)

The objective of this research is to demonstrate the utility of synthetic aperture radar in ice sheet studies. The major advantage of SAR imagery over visible imagery is the all-weather capability of radar and the ability to specify look angle. Available digital SAR imagery over ice sheets has been collected and examined both qualitatively and quantitatively using corroborative data, such as Landsat imagery, to confirm feature identification and interpretations. A simple scattering model will be developed to assess the relative importance of surface topography, composition, and subsurface layering to the intensity of radar backscatter. Recommendations of system parameters will be made for optimal SAR operation over ice sheets.

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PHYSICAL OCEANOGRAPHY

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Wave/Current Interaction Model

by

A. K. Liu (671)

The objective of the first task is to model the wave-current interaction for the application to remote sensing data via numerical simulations and data comparison. Using the field data of surface current shear, wind condition and ambient wave spectrum, the numerical simulations of directional wave spectrum evolution have been used to interpret and to compare with the aircraft data from Radar Ocean Wave Spectrometer (ROWS) and Surface Contour Radar (SCR) across the front during Frontal Air Sea Interaction Experiment (FASINEX). Depending on the wavelength, angle of attack, current speed and the detailed current meandering structure, these waves may penetrate the front and refract to form a shadow zone in the south side of front. A parametric study for various current meandering profiles and incident wave spectrum under FASINEX environmental conditions is being performed to investigate the sensitivity of wave-current interaction. The wave-current interaction model will be used to assess the background current effects on the wave evolution for the Surface Wave Dynamics Experiment (SWADE) pre-test sensitivity study.

The second task of wave-ice interaction was inspired by the observation of large amplitude waves hundreds of kilometers inside the ice pack in the Weddell Sea, resulting in breakup of

the ice pack. The developed analysis of processes includes the refraction of waves at the pack edge, the effects of pack compression on wave propagation, wave train stability and buckling stability in the ice pack. Sources of pack compression and interaction between wave momentum and pack compression are investigated. Viscous damping of propagating waves in the marginal ice zone are also studied. The analysis suggests an explanation for the change in wave dispersion observed from the ship and the sequence of processes that cause ice pack breakup, pressure ridge formation and the formation of open bands of water. Surface signatures of swell, wind, and eddies are observed in the marginal ice zone by SAR from satellite and airborne radars. It will be an excellent opportunity to study the ocean-ice interaction processes in the MIZ using Alaska SAR Facility.

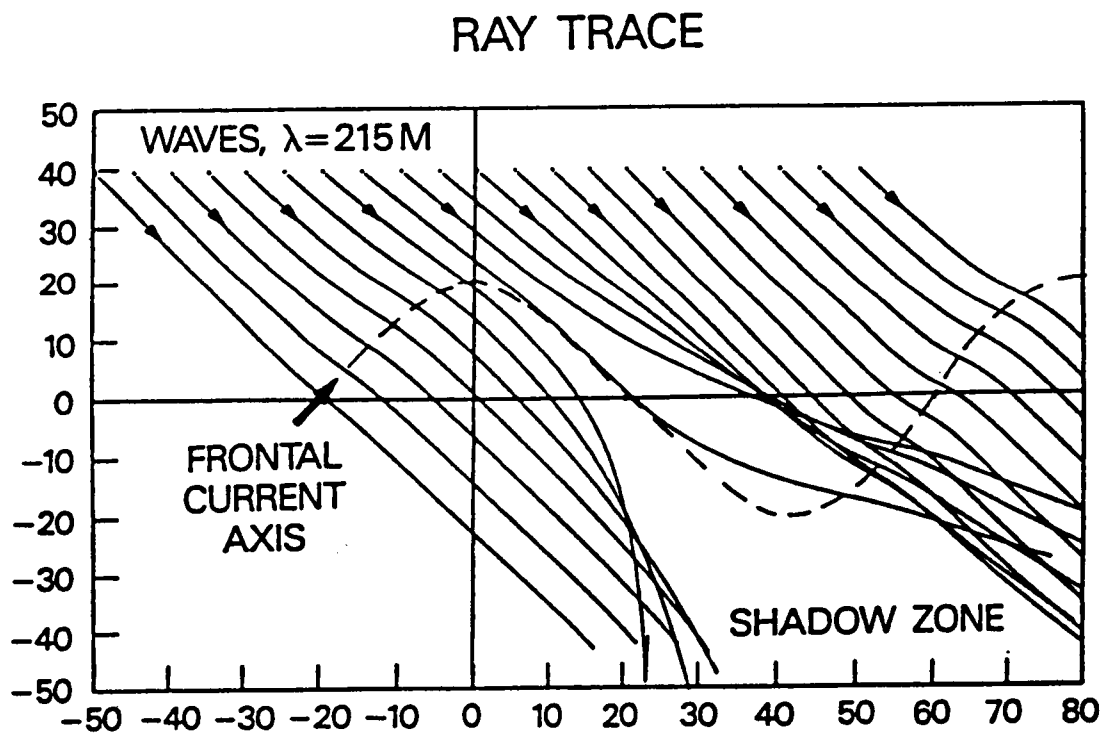
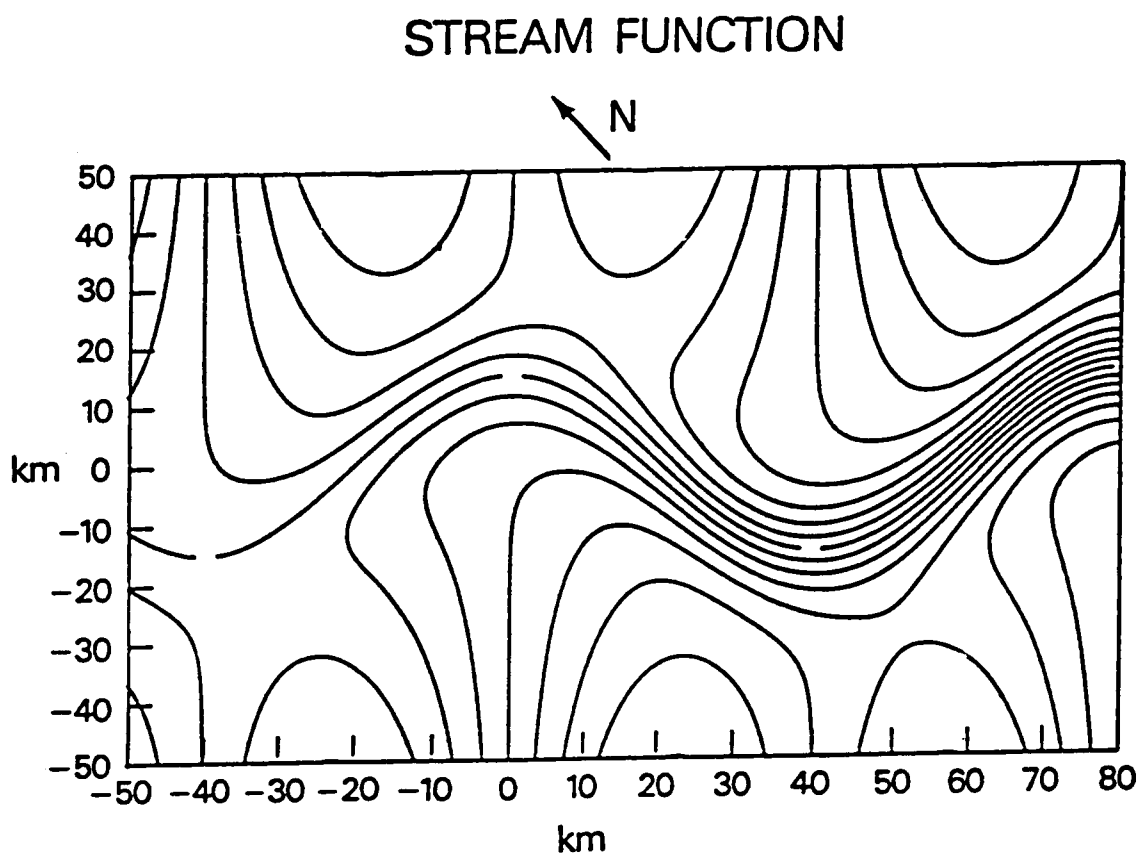


Figure 1. Wave/Current Interaction Model

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OCEAN DRIFTER PROJECT

by

C. D. Mason (674)

Using Erik Mollo-Christensen's Director's Discretionary Funding, four drifting buoys were fabricated in the Code 674 mechanical laboratory from mostly local hardware plus animal locating transmitters made by Telonics in Arizona. The first two working models were dropped from a Wallops aircraft, to test the mechanical integrity and to test the ability of the whole system to withstand the drop and provide usable data. There are two temperature sensors on board, one to measure sea surface temperature and the other to measure air temperature. An on board computer controls the transmissions, sending three water temperature readings for each air temperature reading in order to differentiate one from the other after data reduction. Chuck Mason is the Project Manager; Pete Leone, mechanical engineering; Max Strange, electronic interface; and Bill Jones, data system.

The transmitted signal is picked up by Argos equipment on NOAA 9 and NOAA 10 and relayed back to Landover, Maryland where it can be retrieve by any computer terminal. The location of the buoy is provided by Serviceargos as are four 8-bit words which are reduced by a simple formula to give sea surface and air temperatures.

In October 1987, a drifter was dropped from the Wallops Sky Van, 100 miles east of Wallops Island and drifted freely in and out of the Gulf stream toward the east. Good data was received until early February, when signals weakened and quit, probably due to battery exhaustion, at a location near

58 degrees west longitude.

Two other Goddard drifters and one made by Metocean were deployed in the Bay of Bengal the last week of March to monitor Bay currents and to provide the Bangladesh Government scientists with temperatures and barometric pressure. This is a feasibility study to prove the capability of small, inexpensive, drifting buoys to send back data to aid in the early detection of monsoon weather.

At the present time, we are working on the design of an optical drifter with three sensors in the 430 to 575 nm spectrum to look at upwelled radiances and three sensors in the 430 to 700 nm spectrum to look at incident irradiance. An on-board computer and a photo cell will be used to turn on the transmitter for 3 hours either side of local noon to take advantage of the higher solar elevation angles. This program will provide validation/calibration of the SeaWiFS space-based ocean color sensor and an optical analog to in-situ sea surface temperature observation. Other benefits include gaining experience with long-term optical drifters and providing a minimal biological/optical time series.

Guidelines for the development and test of optical drifting buoys include: air deployable and expendable, reasonable cost for multiple deployment, 1 year lifetime, use of existing technology and a minimal validation parameter set.

The attached drawings show the construction and ocean track of the Atlantic Ocean Drifter and the characterization and typical data of the planned optical drifter.

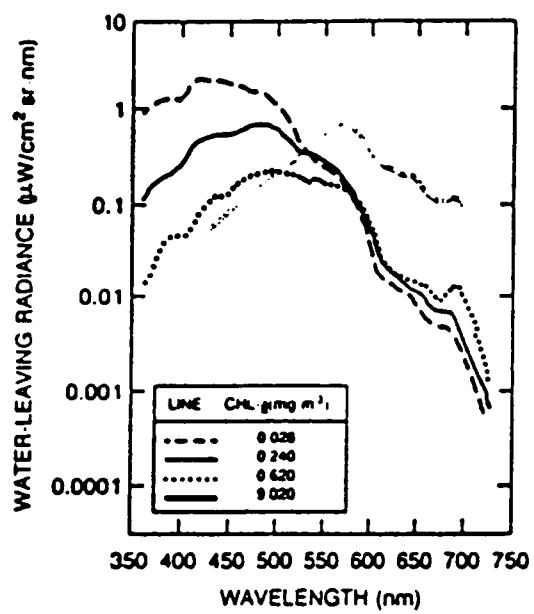


Figure 1a. Water-Leaving Radiance

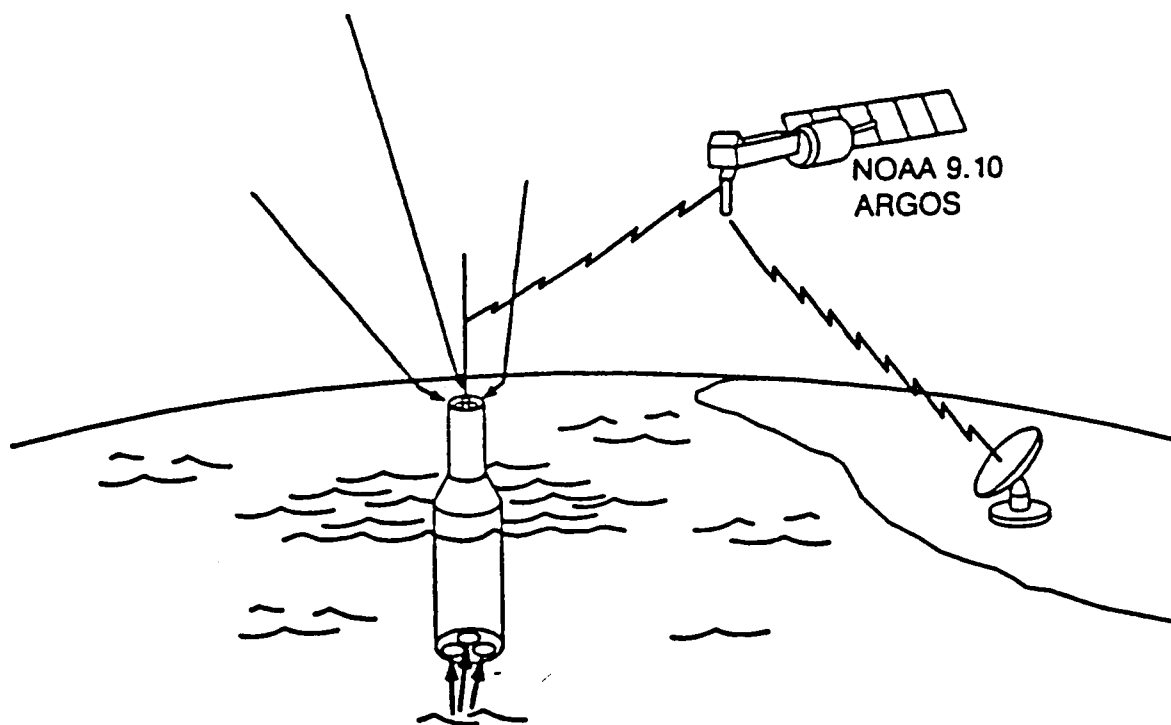


Figure 1b. Optical Drifter

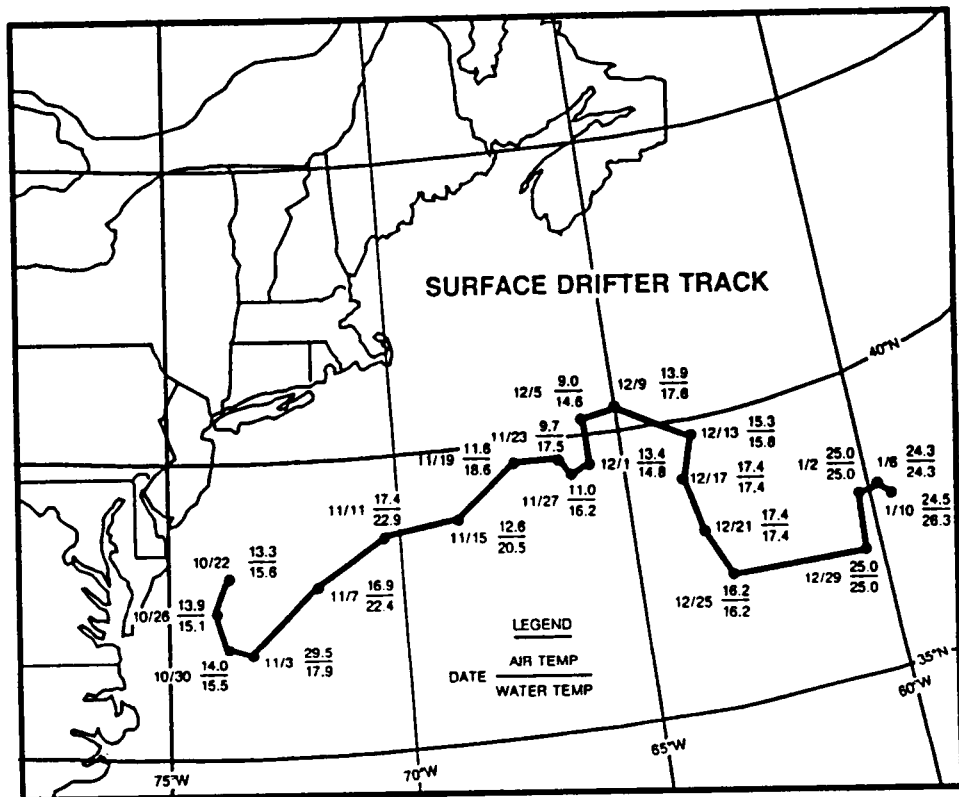


Figure 1c. Surface Drifter Track

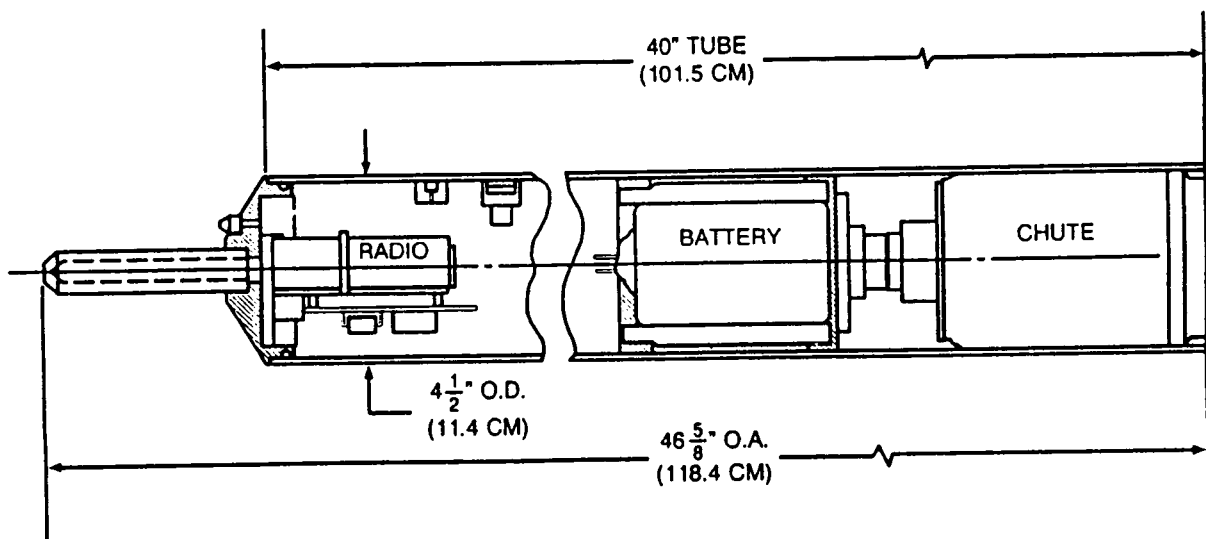


Figure 1d. Air Launched Drifting Buoy



AIR SEA ICE INTERACTION

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ANALYSES OF THE WIND-DRIVEN RESPONSE OF TROPICAL OCEANS

by

A. J. Busalacchi (671)

Numerical and analytical models are used to study the upper-ocean response to surface wind stress estimates from the tropical Atlantic and Pacific Oceans. These models are used to identify regions of important variability in the wind field, analyze the oceanic response, and demonstrate the applicability of remotely sensed vector wind stress and altimetry data. For example, a multi-mode linear model of the tropical Pacific was forced by three different wind products for 1979-1983, namely the FSU ship winds, the UH cloud motion winds, and the FNOC operational product, in order to investigate current capabilities to model upper ocean variability given reasonable estimates of the surface wind stress. Both model and XBT depictions of the mean seasonal cycle, 1979-1981, were analyzed along the major ship tracks in the western, central, and eastern tropical Pacific. Model solutions were also used to address array design questions in observing system simulation experiments. Subsequent analyses of the 1982-1983 solutions will be performed with respect to differences from the mean seasonal cycle 1979-1981, as well as, differences in the three wind products.

Related activities include participation on the Science Definition Team of NSCAT within a project titled "The Impact of NSCAT Winds on Tropical Ocean Modeling". In collaboration with Mark Cane (LDGO) and Vince Cardone (OceanWeather, Inc.), the objective of this work is to assess the value of NSCAT winds for

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improving our ability to specify the state of the upper layers of the tropical ocean via numerical ocean models. TOPEX project activities include "Studies of Tropical Ocean Dynamics Using the TOPEX/POSEIDON Altimeter-Derived Sea Surface Topography". Together with Roger Lukas, Gary Mitchum, and Klaus Wyrtki (UH), studies of tropical dynamics using the TOPEX/POSEIDON altimeter-derived sea level will be carried out in conjunction with the large sea level dataset available at the TOGA Sea Level Center. Another TOPEX project with Eli Katz (LDGO), "Sea-Level Response to Wind Forcing in the Tropical Atlantic," seeks to study interannual variations of the seasonal circulation of the tropical Atlantic via a combination of in-situ observations, satellite observations, and numerical simulations of the sea surface height. In collaboration with Joel Picaut (ORSTOM/Noumea), Thierry Delcroix, and Catherine Gautier (SIO), our POSEIDON project, "Application of TOPEX/POSEIDON Altimetry Measurements to Observation and Modeling Studies of the Low-Frequency Upper Ocean Mass and Heat Circulation in the Tropical Pacific," will enhance the information content of TOPEX/POSEIDON altimetry with in-situ ocean data, satellite-derived surface fluxes and numerical ocean models for the purposes of studying the 4-dimensional variability of mass and heat in the tropical Pacific Ocean.

Ancillary activities include serving as Co-Editor for the Journal of Geophysical Research/Oceans and faculty advisor to graduate students within the Department of Aerospace Engineering Science at the University of Colorado.

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CLIMATOLOGICAL ASPECTS OF NIMBUS-7 SMMR DATA

by

P. Gloersen (671)

An algorithm has been developed for calculating simultaneously SSTs, SWs, and TAUs on a global basis using only the 6.6 and 18 GHz channels of the SMMR. These channels were found to have small and easily correctable drifts over the 9-year SMMR lifetime. Samples of the retrievals have been calculated in each of eight of the SMMR years and found to produce independent results, consistent with weather charts and climatic records, even in the presence of high winds. Another new algorithm for calculating high-latitude scalar winds from Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) data has been devised and tuned with surface observations from a number of documented Arctic Polar Low events. The algorithm utilizes the horizontally and vertically polarized radiances from the 0.8 and 1.7 cm wavelength channels of the ten-channel SMMR to retrieve near surface oceanic scalar winds and cloud water in the column, and takes advantage of the relatively small fluctuations in atmospheric water vapor at high latitudes. An advantage of this algorithm for high-latitude winds from SMMR over the global algorithm is an inherently better spatial resolution as a result of the shorter wavelengths used. Thus retrievals closer to land and sea ice margins are possible. Model calculations were used to determine the effect of cloud water on the multispectral

radiances and the surface observations were used for the wind effect. Surface data sets used for the tuning included detailed weather observations from the 1984 Arctic Polar Lows and the Marginal Ice Zone Experiments, and an archive of polar low events compiled at the Norwegian Meteorological Service for Northern Norway. The estimated standard error of the wind retrievals from the algorithm as it now stands is 10 knots, with a correlation coefficient of 0.82. Spatial resolution is about 50 km, and the sampling interval is about 15 km for the SMMR.

Data from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) have been used to provide a seven-year record of sea ice coverage in the northern and southern polar areas, for the period of November 1978-1985 (See Figure 1.). During this period, the maximum coverage in the Southern Hemisphere was found to be trendless, and to vary $\pm 0.5 \times 10^6$ sq km about a mean of 15.1×10^6 sq km, with a precision of about 0.1×10^6 sq km. The maximum coverage in the Northern Hemisphere was also found to be trendless with a variation even less than in the Southern, ± 0.3 about a mean of 12.9×10^6 sq km. Variations in the minimum sea ice coverage were comparable in the Northern Hemisphere, and smaller in the Southern. The trendless total global sea ice coverage had maxima and minima of 22.5 ± 0.5 and $14.6 \pm 0.5 \times 10^6$ sq km, respectively. If areal variations of sea ice cover are indeed a significant indicator of global climate change, such as an average global temperature change, these data indicate that no such change took place during this period. While the

variations in the extrema of the hemispherical ice covers show no trends, the phase of the oscillations is not constant, resulting in significant changes in the shape of the oscillations of the total global ice coverage.

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MICROSCALE OCEAN DYNAMICS

by

N. Huang (671)

The main goal of this task is to study the detailed dynamics of the micro-scale ocean surface phenomena, and to establish relationships among the surface signatures with the underlying dynamical processes. Our approach to advance our understanding in this area is as follows: 1) Conduct rigorous theoretical studies of the ocean surface wave dynamics and statistical properties. 2) Conduct process-oriented laboratory experiments to verify the theoretical results, and to provide guidance for further studies. 3) Prepare testable hypotheses for field verifications and comparisons during the ONR/NASA sponsored Surface Wave Dynamics Experiment (SWADE).

In the past year, we have established an analytic model for wave breaking probability to study the influence of wave breaking on the spectrum shape in both deep and finite-depth waters. We have also processed the laboratory data on the wave number spectrum and the structures of the water surface under the influence of wind and existing waves. A paper is currently under revision for publication in the Journal of Fluid Mechanics.

Based on our plan for the next three-years, we should be able to produce the following results at the end of the study period: 1) A quantitative assessment on the importance of the Kelvin-Helmholtz instability in wind-wave generation. 2) A quantitative

parameterization of the influence of background waves on the development of centimeter-range waves. 3) A definition of the threshold for wind-wave breaking, and assess the influence on the dynamics of the upper ocean layer. 4) A verification of the influence of the concurrent motions on the weakly nonlinear wave-wave interactions.

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MICROWAVE RADAR OCEANOGRAPHIC INVESTIGATIONS

by

F. C. Jackson (671)

The main thrust of this activity has been, and continues to be, the development and demonstration of the Radar Ocean Wave Spectrometer (ROWS) technique for measuring ocean wave directional spectra from air and space platforms. The measurement technique has been well-demonstrated with data collected in a number of flight experiments involving wave spectral comparisons with wave buoys and the Surface Contour Radar (SCR); recent missions include the SIR-B underflight experiment (1984), FASINEX (1986), and LEWEX (1987). ROWS-related activity is presently concentrating on (1) using the aircraft instrument for wave-processes investigations and (2) obtaining the necessary support (consensus) for a satellite instrument development program. Prospective platforms include Eos and the Canadian RADARSAT.

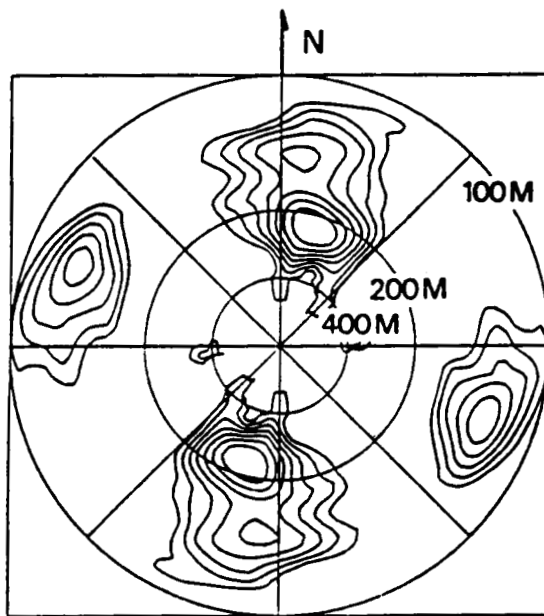
Allied work conducted under this RTOP task includes studies of near-nadir, quasi-specular scatter using the ROWS instrument in a broad-beam altimeter mode configuration and theoretical and empirical studies of the altimeter EM bias. ROWS altimeter mode measurements of the surface Mean Square Slope (MSS) parameter (i.e., the Ku-band frequency effective MSS) in MASEX and FASINEX have been shown to be consistent with a wind speed dependent equilibrium range slope spectrum model. On properly accounting

for diffraction effects using a two scale scattering model, the model spectrum produced MSS in agreement with a consensus of Ku-band data and with the classical optical data of Cox and Munk. A two scale model of the EM bias has been developed for swell dominated conditions that gives a bias in accord with in-orbit estimates (Jackson, 1988).

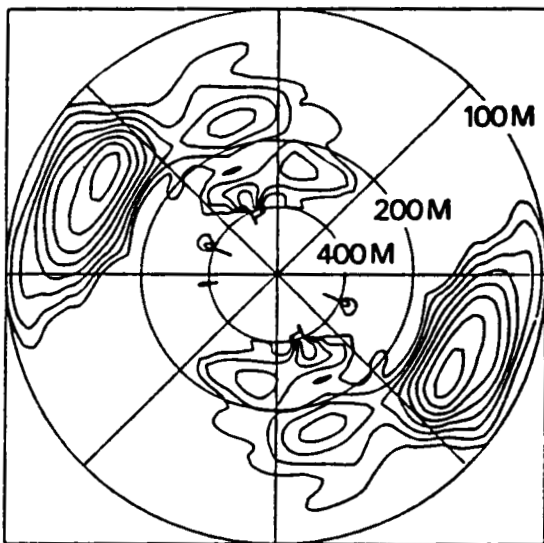
All LEWEX data have been processed and communicated to the Applied Physics Laboratory. Preliminary comparisons with the SCR, Canadian SAR, buoys and wave hindcasts are favorable according the results of a recent workshop held at APL. The wave/current interaction work with A. K. Liu has been reported at the AMS meeting in Anaheim, CA in February (Jackson and Liu, 1988). The refraction of a long (215 m) swell system computed for a simulated flow field in FASINEX (see Liu's figure) was shown to be consistent with both the ROWS (see accompanying figure) and SCR observed spectra on both sides of the oceanic front.

Elements of a new data system for the aircraft ROWS, including a new streaming tape drive and waveform sampler have been checked out. The new data system should be ready for the planned EM bias flights in January-February, 1989. The system is, however, presently limited by the power of the small PC; a better computer is needed to handle the data stream plus the radar housekeeping and aircraft data, and to afford a real time data processing and display capability. It is hoped to have such a capability for

the upcoming Surface Wave Dynamics Experiment (SWADE) in the winter-spring of 1990-91. For this experiment, we plan to transfer the ROWS to the small T-39 Sabreliner aircraft at WFF. Operating on the T-39 at twice the altitude at about 1/10 the cost per spectral degree of freedom relative to the P-3 operation with a turn-key data system will make the flight costs trivial; use of the aircraft ROWS in a "service" capacity also becomes a possibility.



A — NORTH OF FRONT



B — SOUTH OF FRONT

*UNITS: M^{**3}/RAD ; CONTOUR STEPS: 1 dB

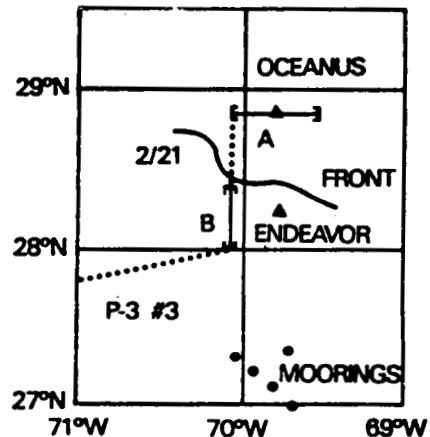


Figure 1. ROWS directional wave-height spectra (DWS) observed north and south of the subtropical front in FASINEX February 21, 1986. Two nearly equal energetic swell systems are evident in the (symmetrical) wavenumber spectrum of the surface waves on the north side of the front, while on the south side of the front the north-south swell is greatly diminished in amplitude. Because the front has meandered into a north-south orientation in the region of the observations, the north-south swell system, which originated in a storm off New England, strikes the front at near grazing incidence and hence experiences strong refraction. A ray trace using an idealized model of the frontal currents by A. K. Liu shows a strong wave, shadow, zone south of the front that is consistent with these observations (see figure 1. in A. K. Liu's activity report).

SURFACE CONTOUR RADAR (SCR) CONTRIBUTIONS TO FASINEX

by

E. J. Walsh (672)

The SCR was asked to participate in the Frontal Air-Sea Interaction Experiment (FASINEX) to provide directional wave spectra. The NASA P-3 carrying the SCR, the Radar Ocean Wave Spectrometer, and the Airborne Oceanographic Lidar was one of five aircrafts and two ocean research ships participating in this coordinated study of the air-sea interaction in the vicinity of a sea surface temperature front near 28° N, 70° W. Analysis of data from the February 1986 experiment is still ongoing, but results already submitted for publication strengthen the hypothesis that off-nadir radar backscatter is closely correlated to wind stress. The SCR provided valuable information on the directional wave spectrum and its spatial variation. The right side of the figure shows one of the directional wave spectra measured by the SCR on February 18. The wave pattern was complex, and the synoptic weather maps on the left of the figure indicate the sources for the trimodal system. In addition to the locally generated waves, there was westward propagating swell generated by the circulation around the high pressure dominating the region on the previous day, and southward propagating swell generated 3 days earlier by a low pressure region off Nova Scotia. The SCR data indicated that the wave height decreased north of the front which was consistent with the observed decrease in the neutral drag

coefficient. The SCR is presently being upgraded so it can produce higher quality directional wave spectra and provide them in real-time.

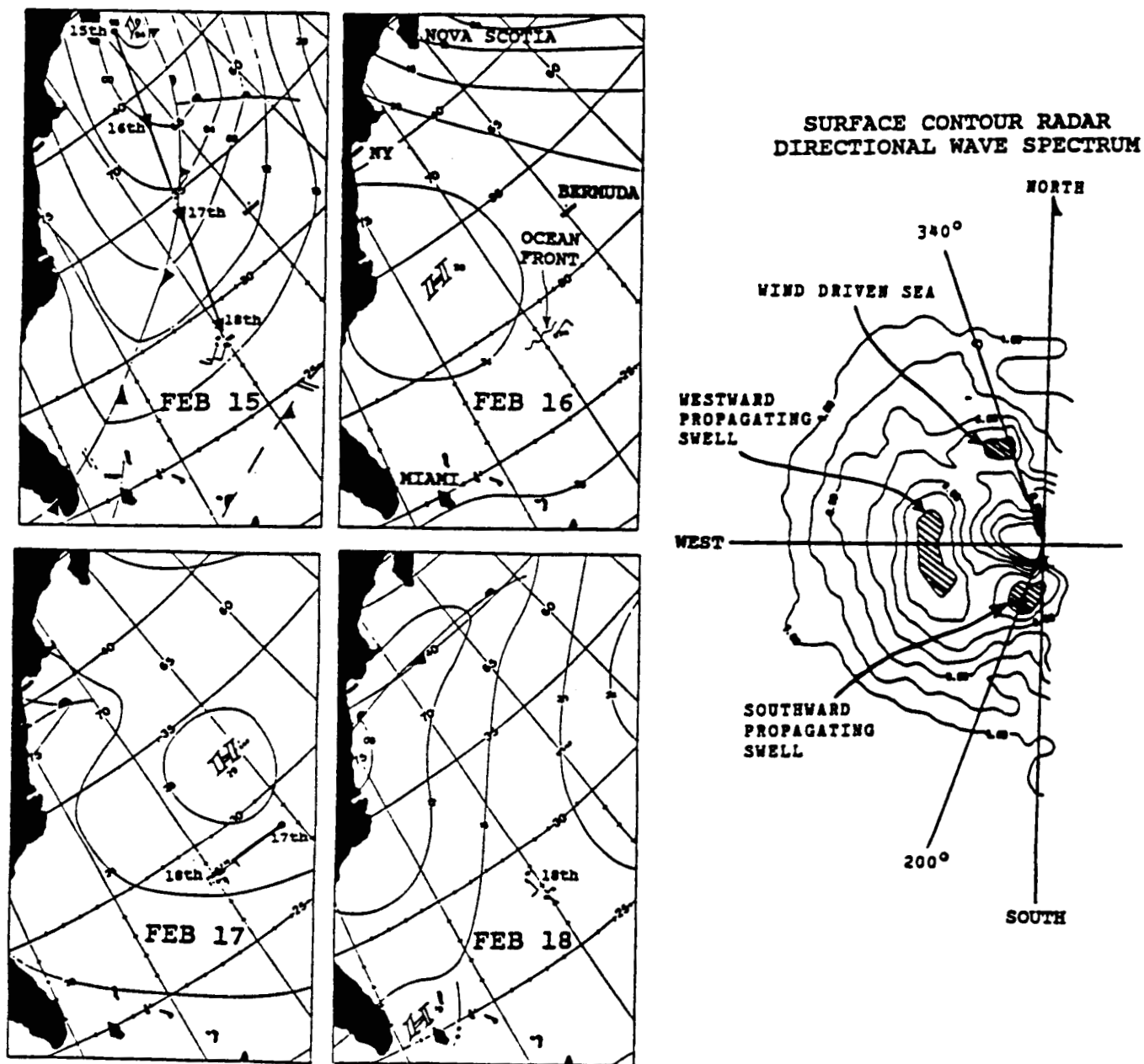


Figure 1. Frontal Air-Sea Interaction Experiment (FASINEX)
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RAINFALL ON MICROWAVE RETURN FROM THE SEA SURFACE

by

L. F. Bliven (672) and J.-P. Giovanangeli¹

Our long range goal remains unchanged--conduct experiments and develop/test theoretical models to permit useful algorithms to be constructed for microwave systems that observe oceanic processes. This topic is relevant to altimeters, scatterometers, and rain rate measurements. We currently are focusing attention on scatterometer wind velocity measurement. In the future, we plan to also investigate (a) the modification of altimeter cross-section due to rain--which is relevant to altimeter derived wind speed, and (b) bistatic scatter angle modification due to rain--which is significant to radar measurement of rain-rate by sensor proposed for the Tropical Rainfall Measurement Mission.

One component of our laboratory efforts is an experiment conducted, in the wind-wave tank at the GSFC/WFF, to quantify the effect of rain-generated surface-wave brightening of radar cross-section. Laboratory conditions can be characterized as light wind, functional rain rates, a single drop size, and a 36 GHz radar system at 30 degrees inclination. This study set a standard for future experiments because these are the first observations to reveal a possible functional form for modelling this process. During the remainder of FY88, we plan to: (1) investigate the effect of drop size on the cross-section brightening by rain-wave generation, and (2) conduct an

experiment¹ at the Institut de Mechanique and Statistique de la Turbulence in Marseille, France, to check the feasibility of making measurements at azimuthal angles so that scatterometer directional response during rain can be quantified.

Our primary enterprise during FY89 will be to conduct experiments to quantify the effect of rain attenuation on existing wind-waves as observed by scatterometers. This requires construction of a 15- by 1.5-foot rain simulator. Design and testing of the simulator concepts have been conducted so that construction can proceed in a timely manner. The completed system will: (a) control rain rate by varying pressure on the water supply, (b) control drop size by air-jets blowing drops off each water nozzle, and (c) provide realistic raindrop distributions by microprocessor control of the air-jets.

The main research topic for FY89 is to conduct experiments to test Manton's 1973 model of rain-attenuation of wind-waves.

¹Institut de Mechanique and Statistique de la Turbulence

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WIND-WAVE-CURRENT TANK RESEARCH FACILITY
USAGE AND STATUS

by

L. F. Bliven and S.R. Long (672)

This summary is to provide information as to: (a) research activities, and (b) facilities status of the wind-wave-current tank research facility located at the GSFC/WFF.

Research Activities:

Our intention is simply to identify research activities so details of particular topics may be obtained from the investigators participating in each activity.

(1) Wave-Turbulence Interaction: N.E. Huang, S.R. Long, and D. Fry [David Taylor Modelling Basin (DTMB)]. New study for which investigatory experiments were conducted to test new turbulence generator and laser-Doppler anemometry measurement capability. Preprocessing of data was conducted on-site, and post-processing is being conducted at DTMB.

(2) Velocity Structure Below Waves: J. Papadimitrakakis (National Research Center), N.E. Huang and S.R. Long. A continuing study of water velocity in the near surface region, below surface waves; laboratory preparation complete.

(3) Short-Wave Modification by Long-Waves: J. Chu and O.M. Phillips (both from The Johns Hopkins University), N.E. Huang, and S.R. Long. A new study to investigate the effects of a packet of long waves on local wind generated wave field.

Experiments were conducted, and data are being analyzed at WFF.

(4) Wind-Wave Generation Time Scale: S.R. Long and N.E. Huang. Ongoing research to determine time scales involved with local generation of wind waves as a function of initial surface conditions being either a calm water surface or paddle generated background waves. Experiments were conducted, and data are being analyzed at the WFF.

(5) Wave-Current Interaction: N.E. Huang, S.R. Long, and R. Lai (David Taylor Modeling Basin). Ongoing investigation for which experiments were conducted to examine the strong interaction between currents and surface waves. Experiments have been conducted, and data have been analyzed at the WFF.

(6) Rain Effects on Microwave Scattering from the Sea-Surface: L. F. Bliven, G. Norcross (Computer Science Corporation) and J.-P. Giovanangeli [Institut de Mechanique and Statistique de la Turbulence (IMST)]. New investigation to measure and model modification of microwave signal from sea surface due to rainfall effects. Experiments and data analyses were conducted/scheduled for both the WFF and the IMST.

(7) Gas Exchange Rates versus Scatterometer Power: R. Wannikohf (Lamont-Doherty Geophysical Observatory), D. Glover (Woods Hole Oceanographic Institute) and L.F. Bliven. New investigation to derive empirical relationships between gas exchange rates and sea-surface scattered, radar-power levels. Experiment design was agreed upon.

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THE SURFACE WAVE DYNAMICS EXPERIMENT (SWADE)

by

S.R. Long, J.D. Oberholtzer, C.W. Wright, and H.G. Shirk (672)

SWADE was developed to study the dynamics of the wave field development in the open ocean with the following specific objectives:

- (1) to understand the development of the wave directional spectrum under various conditions,
- (2) to determine the effect of waves on the air/sea transfers of momentum, heat, and mass,
- (3) to determine breaking distributions as a function of sea state, wind, and boundary stability, and
- (4) to provide data and analyses for ERS-1 validation.

The experiment is designed for the Winter of 1990-1991. Four buoys will be deployed for 6 months starting October 1990 and ending March 1991. During that time period, three intensive periods of 2 weeks duration each will be selected for frequent aircraft flights for wave data collection to satisfy scientific studies, as well as ERS-1 validation needs.

Experiment Location

The buoys will be located at the corners of a square of approximately 100 km on each side, and centered at 37° N and 74° W. This location is about 200 km due east off the Wallops Flight Facility, just off the continental shelf in the deep ocean. Based on available statistics, the buoys will be outside the Gulf Stream proper, with a slight possibility of encountering

occasional meanders and some warm core rings near the conclusion of the deployment.

Management and Wallops Personnel

The Goddard portion of the SWADE project will be under the overall direction of Norden E. Huang. He is one of the initiators of the SWADE project. His other duties include analytic modeling of the probability structures and dissipation source function, investigating the possible impact of Kelvin-Helmholtz instability on the wind wave generation, and assisting the validation of the scatterometry.

Steven R. Long will be the Chief for the ground operations at Wallops. Additionally, he will be the primary investigator for the probability structure of the ocean surface wave field and the co-investigator with N. E. Huang and A. K. Liu in assessing the new possibility of wind-wave generation mechanisms. Erik Mollo-Christensen, supported by ONR, will develop the telemetry system for all the ground data collection. He will also assist and supervise the data archiving and other theoretical investigations.

David Oberholtzer will be responsible for data archiving. He will be assisted by a full-time data technician, Helen Shirk, at Wallops, and also by Erik Mollo-Christensen for this duty. Wayne Wright will assist Erik Mollo-Christensen in the development of the central on-board computers and telemetry systems.

For further information on Project SWADE, contact N.E. Huang at the GSFC or S.R. Long at the GSFC/WFF.

ATMOSPHERIC MEASUREMENTS

WATER VAPOR PROFILING USING MICROWAVE RADIOMETRY

by

J. R. Wang and T. T. Wilheit (675)

Water vapor is one of the most important constituents in the Earth's atmosphere. Its spatial and temporal variations affect a wide spectrum of meteorological phenomena ranging from the formation of clouds to the development of severe storms. It provides an important input to tropical numerical weather prediction and energy budget studies, because the latent heat release due to condensation is crucial to the evolution of many tropical weather systems and is an important energy source to the global scale Hadley and Walker circulation cells. These considerations point to the need for effective and frequent measurement of the distribution of atmospheric water vapor, and therefore, the need for the development of efficient remote sensing techniques. The passive microwave technique offers an excellent means for water vapor measurements. It can provide both day and night coverage under most cloud conditions.

Two water vapor absorption features, at 22 and 183 GHz, have been explored in the past years. The line strengths of these features differ by nearly two orders of magnitude. As a consequence, the techniques and the final products of water vapor measurements are also quite different. At 22 GHz the atmosphere, in clear conditions, typically absorbs less than 20 percent of the radiation propagating through it. Most of the attempts to retrieve water vapor by remote measurements near this frequency

are, therefore, limited to total precipitable water. On the other hand, the strong absorption line at 183 GHz offers the potential of profiling the atmospheric water vapor. In fact, all the past studies of this absorption feature for remote sensing application have emphasized the retrieval of atmospheric water vapor profiles. Our effort in the early 1980's concentrated on the development of both sensor technology and retrieval algorithms at 183 GHz for profiling atmospheric water vapor. The Airborne Microwave Moisture Sounder (AMMS) was the result of this sensor development effort. Using this sensor, retrieval of water vapor profiles under clear sky conditions was successfully demonstrated. As a result of this combined science and technology program, this approach to the measurement of water vapor profiles is currently being implemented for both the NOAA and DMSP satellites and is also planned for inclusion in the Eos payload.

Our research effort in the past few years has been to improve and extend the retrieval algorithm to the measurements of water vapor profiles under cloudy conditions. In addition, the retrieval of total precipitable water using 183 GHz measurements, but in a manner analogous to the use of 22 GHz measurements, to increase measurement sensitivity for atmospheres of very low moisture content was also explored. A combination of both these techniques was used to retrieve the total precipitable water over the coastal Atlantic Ocean during a cold air outbreak which was observed by the AMMS on board the NASA ER-2 aircraft during the 1986 Genesis of Atlantic Lows Experiment as shown in figure 1.

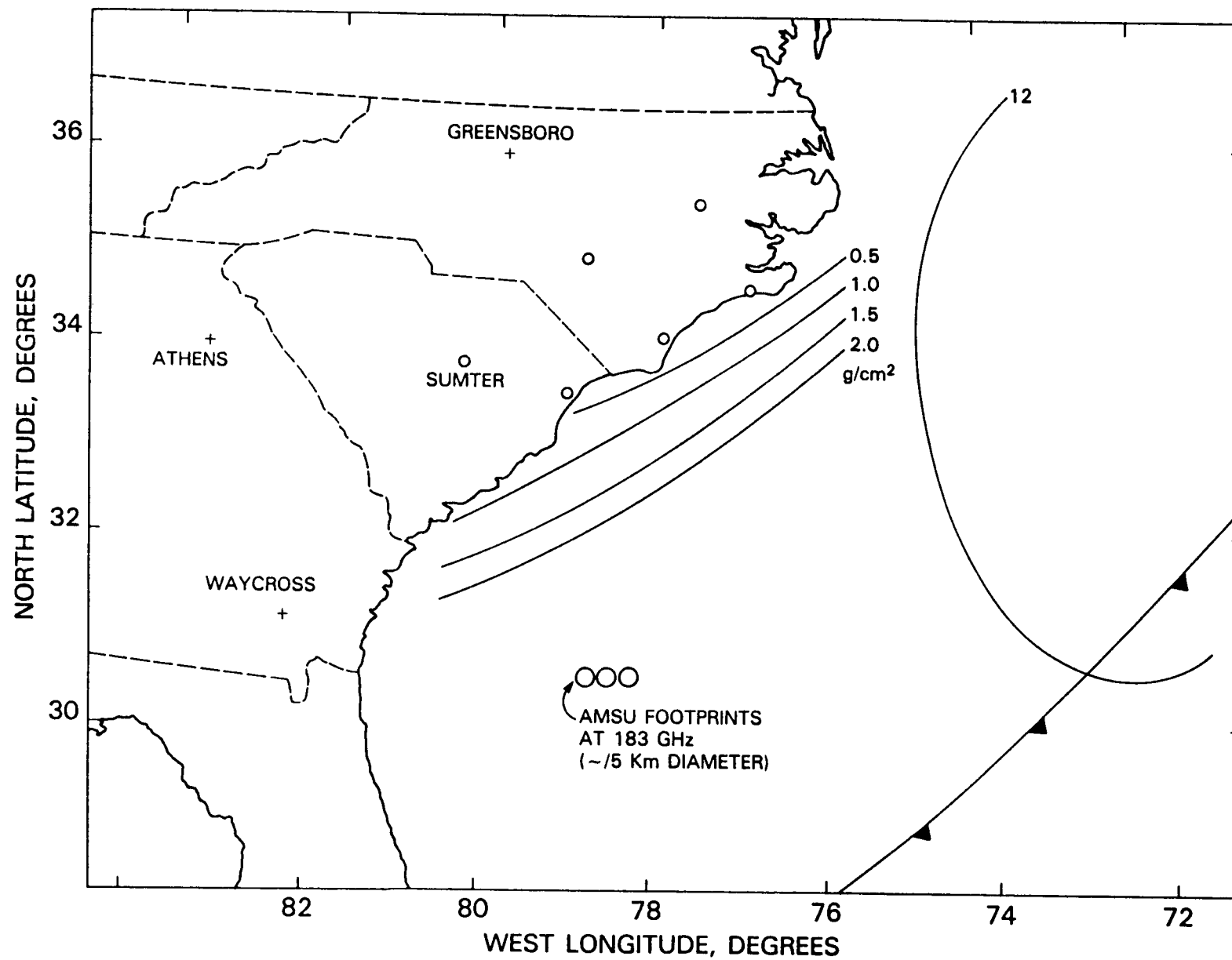


Figure 1. 1986 Genesis of Atlantic Lows Experiment

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CORRELATIVE MEASUREMENTS PROGRAM

by

C. L. Parsons (672)

1987 can legitimately be called the year that ozone trend detection became a public issue in the U. S. In the Fall of 1986, an interagency Antarctic Ozone Expedition Team, known as the National Ozone Expedition (NOZE), spent the months of August-November in Antarctica. They conducted a coordinated series of ground- and balloon-based observations to study the disappearance of stratospheric ozone reported by Farman et al. of the British Antarctic Survey. The NOZE results verified the report that the ozone level was diminished by as much as 90 percent at some altitudes and that the reduction increased every year. At the same time, unpublished reports were circulated stating that the ozone amounts around the entire globe were decreasing at the rate of about 1 percent per year. It is known that an ozone decrease can be associated with an increased risk of skin cancer in humans. Consequently, the Antarctic and global results heightened interest in ozone trend detection. In the Fall of 1986, NASA, in conjunction with the World Meteorological Organization and the United Nations Environment Program, initiated a major review on the subject of ozone trend detection with a report on the findings due by the end of 1987.

An Ozone Trends Panel, composed of eminent scientists from federal agencies, industry, and universities, was formed.

Chaired by Dr. R. Watson of the Upper Atmosphere Programs Office of NASA Headquarters, the Panel contains Calibrations, Algorithms, Satellite/Satellite Intercomparisons, Satellite/Ground Intercomparisons, Comparison of Theory and Observations, Other Trends in Stratosphere, Source Gases, Aerosols, Antarctic Ozone, and Temperature Working Groups. The GSFC Correlative Measurements Program (UPN 665-70) at the Wallops Flight Facility was represented on the Satellite/Satellite Intercomparisons Working Group. The Correlative Measurements Program uses the Rocket Ozonesonde (ROCOZ-A) and the Electrochemical Concentration Cell (ECC) balloon-borne ozonesonde to measure the vertical profile of ozone amount in the atmosphere. The balloon work is described in a separate report in this volume entitled "Ozone Measurements Using Balloon-Borne Ozonesondes," by Arnold L. Torres. The ROCOZ-A instrument has been used for many years to provide in situ "truth" data for various satellite ozone measuring systems, such as SBUV on Nimbus-7, SAGE-II, SBUV-II on the NOAA series of polar orbiting satellites, SME, LIMS, etc. The particular data sets of interest to the Ozone Trends Panel Working Group were collected at Natal, Brazil.

During an experiment at Natal in March and April of 1985, it was found (Barnes, et al., "Equatorial Ozone Profiles From the Ground to 52 km During the Southern Hemisphere Autumn," Journal of Geophysical Research, Vol. 92, No. D5, May 20, 1987, pp. 5573-5583) that the atmospheric variability is negligible. Therefore,

a small number of ROCOZ-A vertical ozone profiles can be compared with high precision with a larger number of satellite ozone profiles in that area and in the same time frame without requiring time coincidence. This reduces the cost of the field experiment and reduces the complexity of the launch schedule. This makes the Natal area in March and April an ideal location to use the rocket profiles to tie together various satellite instruments.

The major results produced for and used by the Ozone Trends Panel are shown in figure 1. The ROCOZ-A average ozone density profile is plotted versus altitude on the left. ECC ozonesondes were used for the portion of the profile below 20 km, the lower limit for ROCOZ-A. In the center graph, the difference between SAGE-II and ROCOZ-A average density profiles is shown. Between 25 and 50 km, the differences are sometimes negative and sometimes positive, they never exceed 5 percent, and average about -1 percent (ROCOZ-A on average is slightly higher). In the right-hand graph, the difference between ROCOZ-A and the SBUV results from Nimbus-7 are plotted. This comparison is made in terms of ozone layer amount versus Umkehr layer, the primary ozone data product from the SBUV. For all layers, the differences are all negative. That is, the SBUV values are less than ROCOZ-A. The difference is 18 percent at layer 9 and 5 percent at layer 6. This result is discussed in further detail by Barnes ("Changes in SBUV Ozone Profiles Near Natal, Brazil, from 1979 to 1985," Journal of Geophysical Research, Vol. 93, No. D2, February 20, 1988, pp. 1704-1717).

The implication of the Natal data sets and the analyses by Dr. Barnes (Chemal, Inc.) resulting from them is that the SBUV vertical profile shape is inconsistent with atmospheric behavior. Instrumental effects in the SBUV that are improperly accounted for in the Nimbus-7 data processing may be responsible. The recently published report by the Ozone Trends Panel does indeed indicate that findings from the other Working Groups agree with ours. The report does conclude that an ozone decrease on a global scale is real, however. Although the earlier reports of a decrease were considerably exaggerated because of the SBUV instrument problem, the Earth's ozone amount is decreasing. In the future, even more attention will be paid to the close monitoring of the global trend. We expect that the ROCOZ-A measurement will continue to be of importance in this effort.

OZONE DENSITIES AT NATAL, BRAZIL
MARCH/APRIL 1985

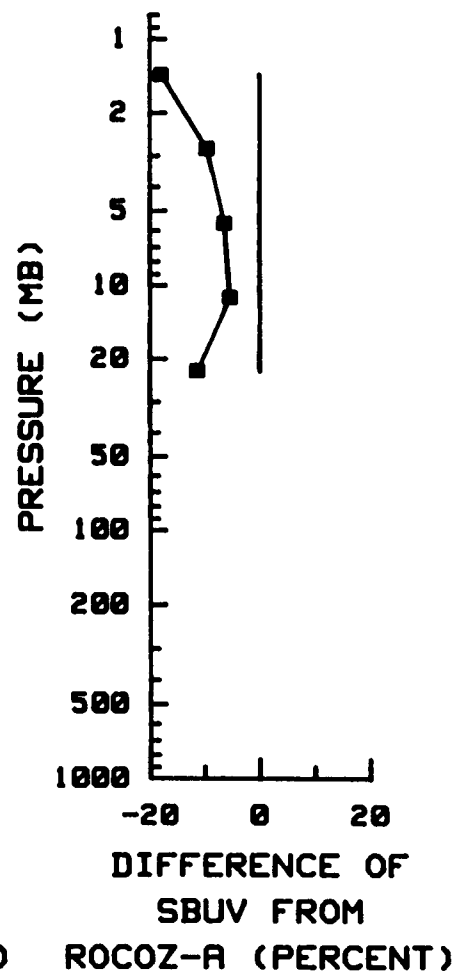
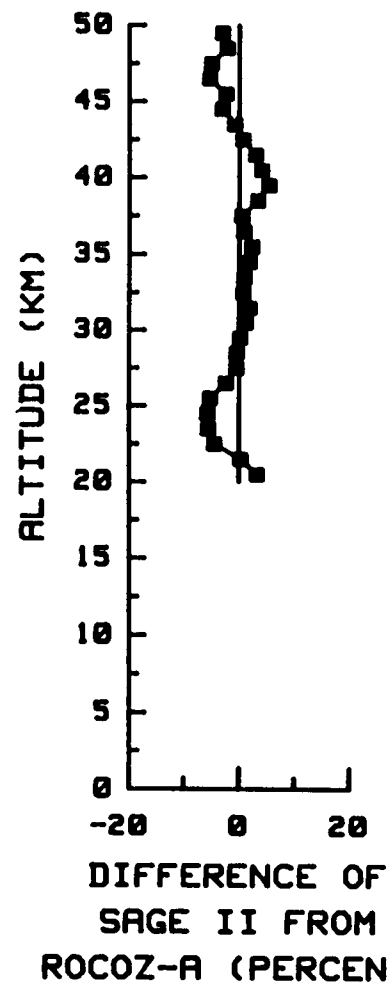
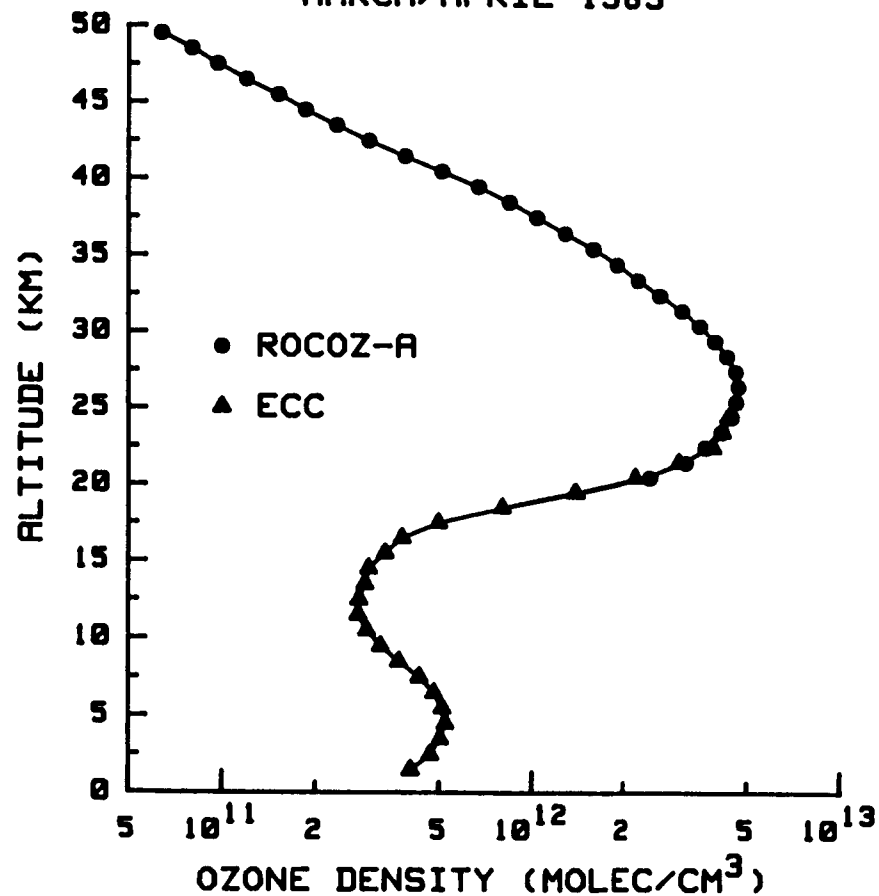


Figure 1. The ROCOZ-A Average

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OZONE MEASUREMENTS USING BALLOON-BORNE OZONESONDES

by

A. L. Torres (672)

Vertical profiles of atmospheric ozone have been measured for a number of years by WFF personnel using small balloon-borne ozonesondes. These sondes are interfaced with meteorological radiosondes so that both ozone data and meteorological data (pressure, temperature, humidity, wind speed and direction) are obtained from ground level up to 30-35 km.

Efforts at Wallops have been focused in three areas. The first involves biweekly launches from two sites (Wallops and Natal, Brazil), timed to coincide with overpasses of satellite-borne ozone sensors such as the Solar-Backscattered Ultraviolet. The resulting data are reported to the World Ozone Data Center and are used for satellite correlative support, as well as, for studies of both tropospheric and stratospheric ozone. The second activity consists of field campaigns in remote locations in support of special projects. The third is a continuing activity to quantitatively evaluate and improve the sonde's performance under stratospheric conditions.

The most recent field campaign involved measurements of ozone over Palmer Station, Antarctica, during August-October of 1987. The Wallops effort was part of both NASA's Airborne Antarctic Ozone Experiment and the National Science Foundation's National

Ozone Expedition. Both of these experiments were aimed at studying the annual stratospheric ozone depletion that has happened each austral spring in recent years. This year, the amount of depletion was larger than ever. Total column amounts of ozone decreased by more than 50 percent between August and early October, while ozone concentrations in the 17 km region decreased by over 95 percent. As shown by other investigators, the ozone depletion is approximately confined to the polar vortex. Because of meteorological distortions in the boundaries of this mass of air circling the polar region, Palmer was within the region of depleted ozone on some days, and not on others. Figure 1 shows the dramatic depletion that had occurred at 50-100 mb altitudes in air that was within the ozone-depleted region (October 9) compared to the more normal profile of October 6.

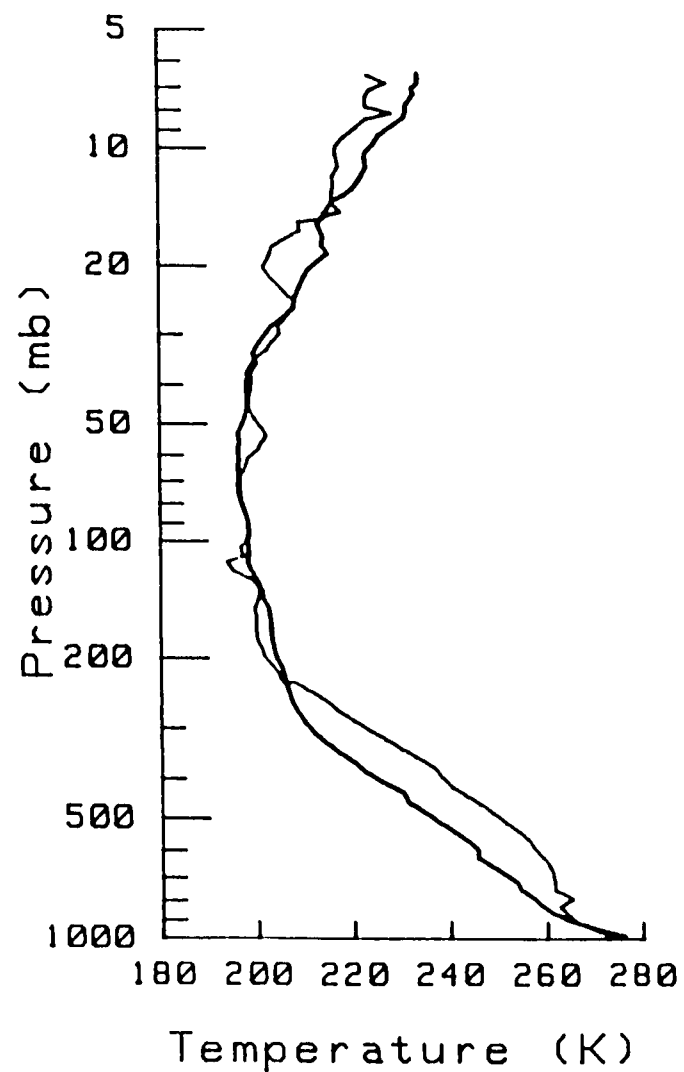
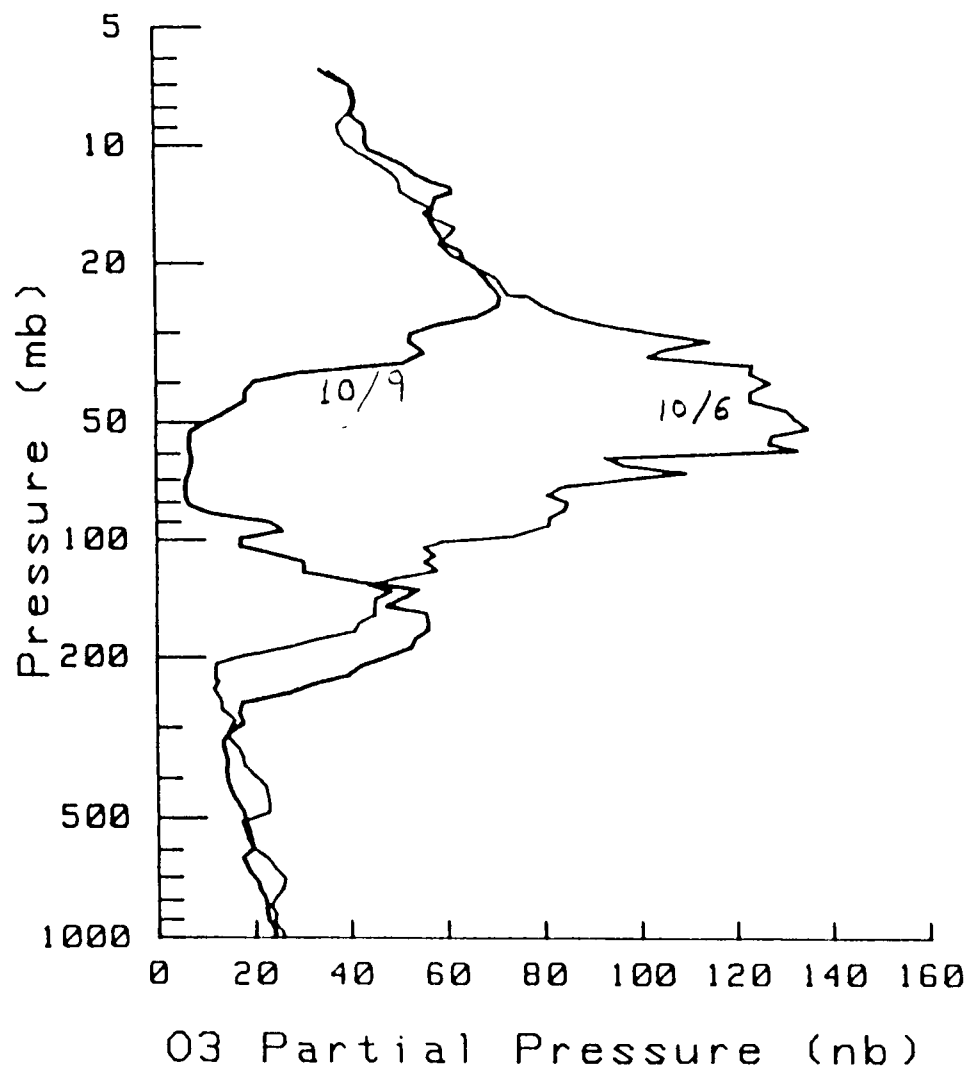
Planning is underway for a second trip to Palmer in the austral Spring of 1988. This experiment will provide information on whether the ozone "hole" continues to deepen and spread, both in horizontal and vertical extent.

Sensor evaluation studies have involved both flight tests and laboratory studies using a flight simulator. The Balloon Ozone Intercomparison Campaign flights in 1983 and 1984 provided the chance to test small ozonesondes relative to research-grade instruments on a large balloon platform. During this same time period, a laboratory-based flight simulator was designed and constructed at Wallops. The flight simulator exposed a sonde to

typical vertical profiles of ozone, pressure, and temperature while monitoring the sonde's performance. These studies resulted in a well-characterized knowledge of the sondes accuracy and precision as a function of altitude. Recent efforts have concentrated on designing and constructing an improved version of the flight simulator. This is now complete, and first applications are underway. Planned studies include an evaluation of accuracy and precision for the newer model ozonesondes now being used at Wallops, tests to higher altitudes, and quantitative determinations of how such factors as sensing-solution concentration and preparation procedures affect sonde performance.

10/6/87

10/9/87



PALMER STATION, ANTARCTICA

Figure 1. Ozone Profiles Measured Within (10/9) And Outside (10/6) Ozone-Depleted Air Mass

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MOBILE LIDAR SYSTEM FOR MEASUREMENT OF
WATER VAPOR MIXING RATIO AND OZONE NUMBER DENSITY

by

D. Whiteman (674)

The Code 674 Water Vapor Lidar has been modified and extended by Codes 674 and 617 to make differential absorption measurements of ozone. The Water Vapor Lidar group consists of project scientist Harvey Melfi, meteorologist/data analyst Rich Ferrare, and systems engineer/project manager Dave Whiteman. The Ozone Lidar group consists of project scientist, Tom McGee, laser physicists Jim Butler and John Burris, Rich Ferrare and Dave Whiteman.

All of the lidar equipment is housed in a mobile trailer allowing relocation of the experiment. Both experiments are nighttime operating only. The experimental equipment includes a 70 Hz Xe-Cl excimer laser (308 nm), 10 Hz Nd:YAG laser (355 nm), 30 inch Dahl-Kirkham telescope, custom designed optics package, photomultiplier tube detectors and photon counting signal measurement system. The system is controlled by a DEC LSI-11/73 computer providing experiment control and near real-time graphics output with a vector co-processor used for real-time data processing.

Water vapor measurements make use of a weak molecular scattering process known as Raman scattering. It is characterized by a shift in wavelength of the scattered beam of light relative to the incident one. Some of the energy of the incident photon is

converted to vibrational/rotational energy within the molecule leaving the scattered photon shifted to a slightly longer wavelength. The amount of this wavelength shift depends on the vibrational/rotational energy level structure of the particular molecule being excited and is unique to it. For a photo of certain incident wavelength, therefore, the shifted wavelength of the scattered photon is a signature of the molecule. Melfi (1972) has shown that the ratio of the Raman backscattered signal from water vapor to that of nitrogen is proportional to the water vapor mixing ratio, figure 1., assuming that the atmospheric transmissivity at the two different wavelengths is the same.

When performing water vapor measurements, we are able to acquire profiles of water vapor mixing ratio from near the ground to beyond 7 km every 2 minutes. By forming a color composite image of the individual profiles, the spatial and temporal evolution of water vapor is visible with vertical resolution of 75 - 150 meters and temporal resolution of 2 minutes. During two intensive field missions in 1987, one at Greenbelt, Maryland the other at Falmouth, Massachusetts, we successfully measured the evolution of the water vapor structure during various meteorological significant events such as cold and warm frontal passages and atmospheric gravity waves. During both of these missions, we acquired at least a week of continuous nighttime data.

The ozone lidar is intended for use as a cross-calibration

facility for other stationary ozone lidar systems. This new system is undergoing testing in anticipation of its first field deployment in July 1988, at Table Mountain, California to perform intercomparison measurements with a ozone lidar developed by JPL.

The ozone measurement employs the technique known as differential absorption. The backscattered laser radiation from two different wavelengths is measured. One of these wavelengths is strongly absorbed by ozone while the other is essentially unabsorbed. By comparing the two return signals on a height-by-height basis, one can determine the absorption due to ozone and thus derive the ozone number density, figure 2.

We have successfully measured 308 nm returns from 80 km with an averaging period of 6 hours. Using these data and a standard atmosphere density curve, we have derived an ozone number density profile which agrees very well with the standard ozone curve between 20 and 40 km. We will soon use the Nd:YAG 355 nm data to derive the actual density curve implementing the full differential absorption technique.

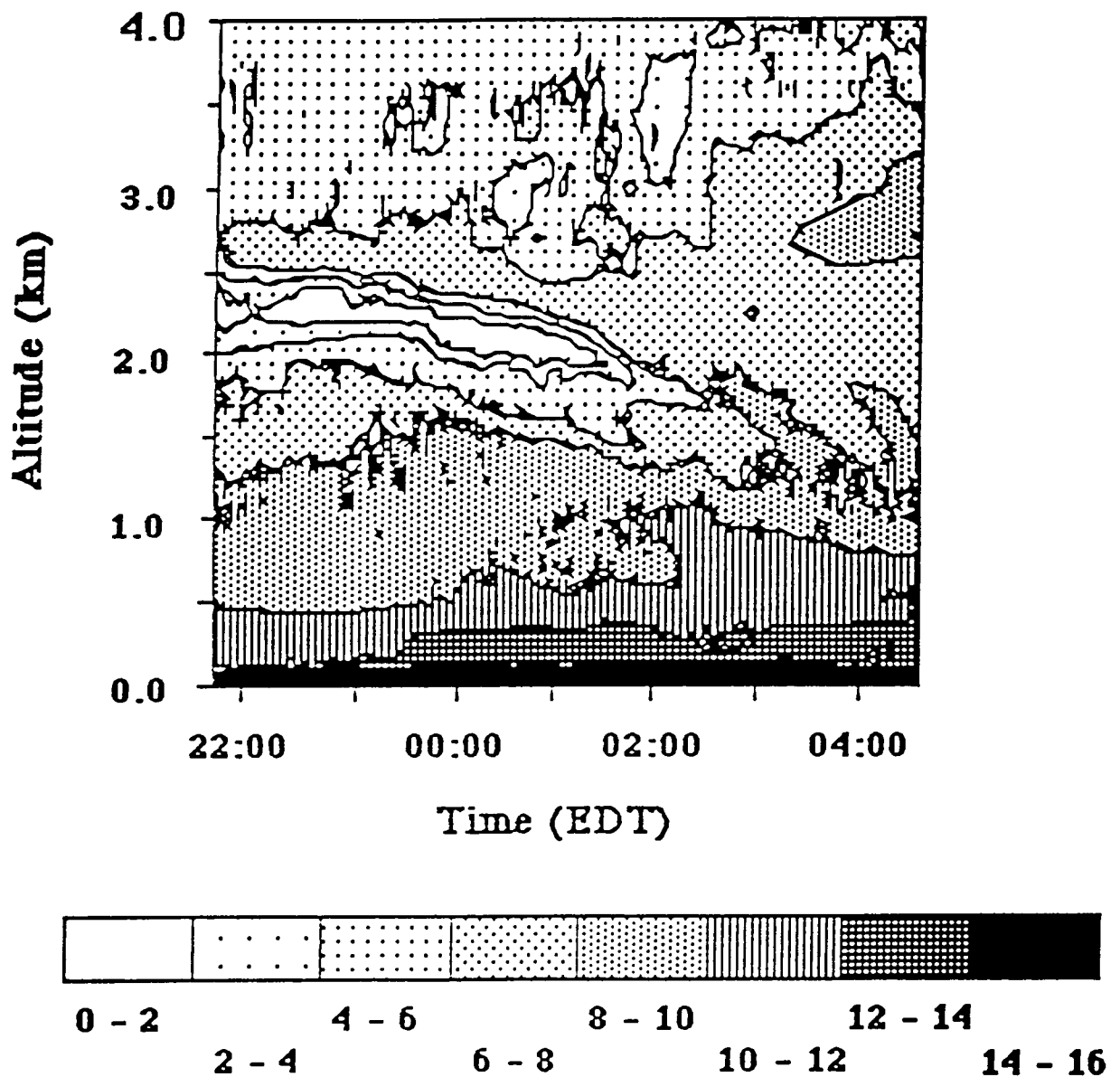


Figure 1. Water Vapor Mixing Ratio (g/kg)
June 6 - 7, 1988

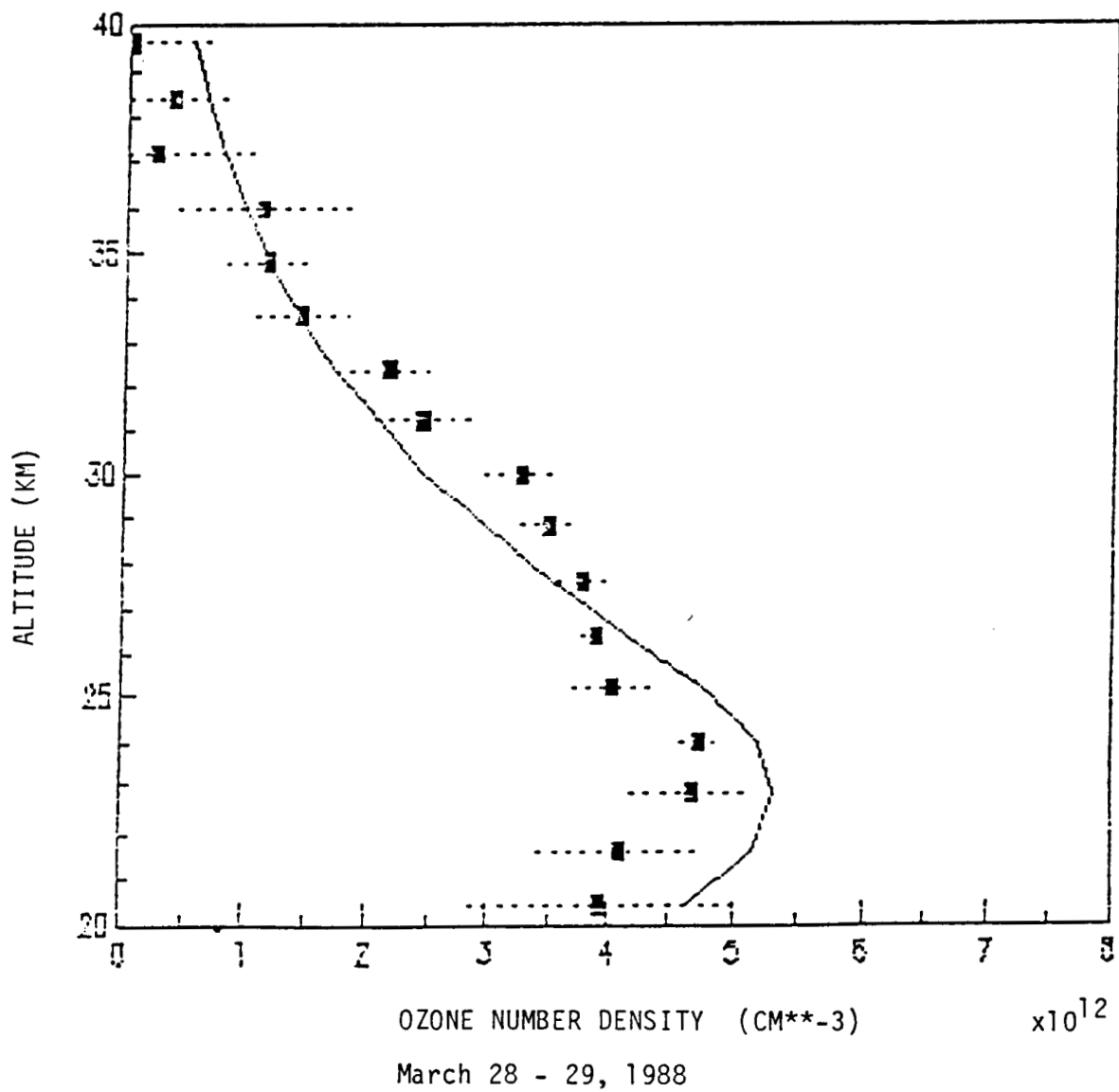


Figure 2.

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ROCKET TEMPERATURE SOUNDINGS

by

F. J. Schmidlin (672)

In situ rocket-borne measurements of temperature and wind contribute to a better determination and understanding of stratospheric behavior and, hence, to a better understanding of processes that control the dynamical and chemical behavior of this region. Rocket-borne measurements provide basic data for satellite validation and calibration over the short- and long-term, and for evaluation of new ground-based systems, such as lidar. Rocketsonde measurements are used for definitive, small-scale studies of atmospheric behavior and permit monitoring of changes occurring in the stratosphere. This long-term data set is of extreme value for depicting temperature trends and for their correlation with possible trends in the Earth's ozone shield. During 1986 and 1987, meteorological rocketsonde funding was only sufficient to permit a minimum number of launchings consistent with maintaining launch range expertise and capability.

Concern over ozone depletion and the difficulty generally involved in determining actual ozone trends has generated significant interest in temperature behavior, especially trends. Recent analysis of rocketsonde acquired temperature data between 1969 and 1986 contains evidence that the stratosphere may indeed be cooling. Preparation of material for contribution in the

Report of the Temperature Trends Committee estimates that this cooling trend is $-0.2/0.3^{\circ}\text{C}$ per year. Because the magnitude of this change is small compared to the magnitude of the measurement, the measurement system must possess the capability to provide high resolution. The precision of the present rocketsonde instrument is about $0.6/0.9^{\circ}\text{C}$ for temperature and about 200-300 meters in the vertical between 20 and 55 kilometers; this presently is better than the resolution of any other instrument providing stratospheric measurement data. While radiosondes provide more frequent measurements, their altitude is limited to below 30 kilometers.

A lidar for measuring density (temperature) between 25 and 100 kilometers (current capability is about 25 to 80 kilometers) under development at the Air Force Geophysics Laboratory was compared to meteorological rocketsonde measurements. This comparison took place at the Wallops Flight Facility (1985) and at the Poker Flat Research Range, Alaska (1986). The tests were successful; the comparison showed that substantial agreement exists between this lidar and the in situ data. As a result of these comparisons, lidar design improvements are expected. The lidar Principal Investigator has since moved to The Pennsylvania State University and plans to continue the development of a stratospheric-mesospheric lidar. New comparisons are being considered.

It is the intention of the RTOP to continue to provide

rocketsonde measurements to: 1) maintain the long-term data stratospheric-mesospheric data base already established for Wallops; 2) provide ground truth for remote measurements; and 3) continue studies of atmospheric structure and morphology of disturbances and anomalous events as resources permit.

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ELECTRODYNAMICS, WIND AND TEMPERATURE

by

F. J. Schmidlin (672)

This RTOP provides for correlative meteorological wind and temperature measurements with atmospheric electrodynamic measurements. Meteorological rocketsondes have been launched as part of a number of electrodynamic investigations in Alaska, Norway, Peru, Sweden, and at the Wallops Flight Facility, Wallops Island, Virginia. Measurements obtained as part of the MAC/Epsilon campaign during October 1987 from Andoya, Norway, were in conjunction with electric field, ion mobility, conductivity, and energy deposition studies. Experimenters were from the GSFC, University of Denver, and The Pennsylvania State University. The measurements obtained between 30 and 90 kilometers are to evaluate and correlate changes in the atmospheric electrical structure caused by the neutral wind and temperature, or changes in the neutral atmosphere resulting from electrical anomalies. Previous measurements have been obtained in connection with the occurrence of noctilucent clouds and thunderstorms. Future plans are to study neutral or electrical structure correlations in the above situations and to make wind and temperature measurements in conjunction with studies of polar mesospheric clouds.

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RADIOSONDE INTERCOMPARISON

by

F. J. Schmidlin (672)

NASA hosted Phase II of the World Meteorological Organization (WMO) International Radiosonde Intercomparison at the Wallops Flight Facility in February-March 1985. Phase I had taken place in June-July 1984 at Bracknell, United Kingdom. The comparison produced the largest amount of material ever collected from a radiosonde comparison. Radiosondes from Australia, Finland, India, and the United States were involved. Data were received from 100 soundings, each of which was a simultaneous in situ test of four different instrument types. A fifth instrument was compared on a limited basis. This was the Graw M60 radiosonde manufactured in the Federal Republic of Germany and used by the United Kingdom.

The simultaneous temperature comparison of participating operational radiosondes in daylight was about 1°C at the 100 hPa level and about 4°C at the 10 hPa level, while the corresponding comparison for geopotential was about 40 meters at 100 hPa and 100 meters at 10 hPa. The uncertainty in the observations made using operational radiosondes is today at the 10 hPa level, in degrees and meters, roughly the same order as it used to be at the 100 hPa level 30 years ago. The main reasons for this achievement are improved sensors, receivers, data evaluation, and, in particular, removal of, or correction for, radiation

errors of some of the instruments.

Estimates of the reproducibility of standard level temperatures are give in table 1. Table 1 also includes results from Phase I. The reproducibility obtained from the in situ comparisons is, in general, slightly better than corresponding results from monitoring measurements in a real-time mode at analysis centers. The Indian radiosonde, however, turned out to be considerably better in the instrument comparison than one might infer from monitoring results.

Conclusions from the intercomparison are many; the following call for particular attention: 1) fully automated radiosonde systems were able to reproduce geopotential measurements better than non-automated systems, mainly due to a decrease in observer mistakes. 2) Observed temperature differences between radiosonde measurements were as large during the night as during the day. 3) Significant inconsistencies still exist between the nighttime and daytime measurements, as well as significant bias errors in the pressure measurements of some radiosonde types.

In addition, the Final Report recommends that manufacturers increase automation in order to minimize errors caused by manual treatment of chart records. Also, the automated systems must be provided with standardized instrumental correction procedures to avoid systematic errors.

Table 1

Estimates of the reproducibility of standard level temperature measurement in °C. The estimates are for one standard deviation (Nash and Schmidlin, 1987).

Pressure Level (hPa)	<u>Link Radiosonde</u>		AUS	FRG	IND	UK	BEUK	GRAW	
	FIN I,II	USA I,II							
1000	0.3	0.8,0.4	0.5	0.3	0.7	0.3	0.4	0.5	
900	0.2	0.4,0.2	0.4	0.2	0.7	0.2	0.3	0.4	
850	0.2	0.3,0.2	0.4	0.2	0.7	0.2	0.4	0.4	
700	0.2	0.3,0.2	0.4	0.3	0.7	0.2	0.3	0.4	
600	0.2	0.3,0.2	0.3	0.3	0.7	0.2	0.3	0.3	
500	0.2	0.3,0.2	0.3	0.3	0.7	0.2	0.4	0.4	
400	0.2	0.3,0.2	0.3	0.4	0.7	0.2	0.4	0.4	
300	0.2	0.3,0.2	0.4	0.4	0.7	0.2	0.5	0.5	
250	0.2	0.3,0.2	0.6	0.4	0.7	0.2	0.6	0.5	
200	0.2	0.3,0.2	0.8	0.4	0.7	0.2	0.7	0.6	(0.5)
150	0.2	0.3,0.2	0.8	0.5	0.6	0.2	0.8	0.8	(0.5)
100	0.2	0.3,0.2	0.8	0.5	0.6	0.2	0.9	1.0	(0.5)
70	0.2	0.3,0.2	1.2	0.5	0.7	0.2	1.0	1.3	(0.7)
50	0.3	0.6,0.3	1.2	0.5	0.8	0.3	1.2	1.5	(1.2)
30	0.4	0.8,0.4	1.4	1.0	1.0	0.4	1.4	2.0	(1.2)
20	0.5	1.0,0.5	1.6	1.5	1.5	0.5	1.6	2.0	(1.2)
15	0.6	1.2,0.7	2.2	2.0	2.0	0.6	1.8	2.5	(1.5)
10	1.0	1.5,1.2	3.0	2.5	2.5	1.0	2.0	4.0	(1.5)

Estimates for the USA and Finland reproducibility differ from Phase I to II as indicated. Bracketed estimates for Graw are for nighttime flights only.

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SATELLITE/RADIOSONDE COMPARISON

by

F. J. Schmidlin (672)

Colocated measurements of radiosonde and TIROS Operational Vertical Sounder (TOVS) data are compared to determine whether significant latitudinal, seasonal, or instrumental biases exist. Long-wave structure determined by each system is being examined for correlation. Because US radiosonde data are archived uncorrected, an effort to correct the measurements based on the radiative corrections being developed under RTOP 146-71-06 is being considered. These corrections will be applied to 7 years of measurements. New comparisons will then be made using corrected radiosonde and TOVS data. A regression method is used to retrieve temperatures, and radiosonde zonal means are used to update the regression coefficients. Preliminary results of auto-correlation analysis indicate that detection of long-wave structure in each set of data is slightly different with some levels and locations experiencing different wave periods or amplitudes. Scatter diagrams and linear regression for each layer show bias in the mean temperatures. Winter-time measurements show poorer correlations due to noisy measurements.

Studies planned under this RTOP were delayed over 9 months waiting for contract approvals. The contractor began algorithm development in January and plans to have an operational analysis program completed by late April.

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TROPOSPHERIC NITRIC OXIDE MEASUREMENTS

by

A. L. Torres (672)

Nitric oxide (NO) plays a key role in tropospheric photochemistry. The photochemical oxidation of hydrocarbons, for example, can serve as either a source or a sink for ozone, depending on the local abundance of NO. Nitric oxide also helps govern atmospheric concentrations of the hydroxyl (OH) radical. The OH radical is the single most important player in photochemical transformations because it controls the atmospheric lifetimes of so many chemical species.

Although NO serves as a very effective catalyst in many important chemical processes, its concentration is low enough to normally be expressed in units of parts per trillion by volume (pptv). Consequently, commercially available detectors for NO (with detection limits of about one part per billion) have proven to be unsuitable for use anywhere except in urban areas and near other local pollution sources. Under the sponsorship of NASA's Global Tropospheric Experiment (GTE), Wallops has developed an extremely sensitive detector with a detection limit of a few pptv. The system was specifically designed for aircraft use, with the objective of applying it in global aircraft studies of tropospheric chemistry.

The Wallops instrument has logged several hundreds of flight

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hours on NASA aircraft, primarily through participation in various GTE missions. These include the Chemical Instrumentation Test and Evaluation (CITE-1) missions aimed at demonstrating NO measurement capabilities, the CITE-2 mission to evaluate nitrogen dioxide (NO₂) sensors, and the Amazon Boundary Layer Experiments, (ABLE-2A and ABLE-2B).

The most recent mission was ABLE-2B which took place in April-May of 1987. This mission was designed to investigate tropospheric chemistry over tropical rain forests during the wet season, and complemented the results obtained during the ABLE-2A dry-season mission. Daytime mixing ratios of NO over the Amazon Basin during this mission were among the lowest ever observed over continental areas. The NO mixing ratio averaged 12 pptv for altitudes below 0.3 km and 6 pptv at higher altitudes. These concentrations bracket the level above which tropospheric photochemistry is expected to produce rather than consume ozone. During the dry season, 25-60 pptv was found at the lower altitudes, and 10-12 pptv were common at the higher altitudes. The higher values observed during the dry season reflect a combination of more biomass burning and more active soil-production of NO.

Planning is now underway to develop techniques for measuring other nitrogen species such as NO₂ and total reactive nitrogen.

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CLOUD ABSORPTION RADIOMETER

BY

M. G. Strange (674)

The Cloud Absorption Radiometer (CAR) was developed with Director's Discretionary Funding in 1983-84 for Dr. Michael King, Code 615, and has been flown successfully many times aboard the University of Washington's C-131 cloud physics airplane under a National Science Foundation grant. Its purpose is to measure spectrally how light is scattered by clouds and to determine the "single scattering albedo", important to meteorology and climate studies, with unprecedented accuracy. This measurement is based on ratios of downwelling to upwelling radiation within clouds, and so is not strongly dependent upon absolute radiometric calibration of the instrument.

The CAR has a 5-inch aperture and 1 degree IFOV, and spatially scans in a plane orthogonal to the flight vector from the zenith to nadir at 1.7 revolutions per second. Incoming light is measured in 13 spectral bands, using silicon, germanium, and indium-antimonide detectors. Data from each channel is digitally recorded in flight with 10-bit (0.1%) resolution.

The instrument incorporates several novel features. Since it is flown through clouds, moisture may occasionally collect on the scan mirror, producing an error. To test for water on the mirror, a thin beam of light reflected from the edge of the mirror is monitored by a photodiode. Any fogging of the mirror

scatters the light beam, reducing the specular component detected by the photodiode and flagging any stretches of faulty data. Another feature ensures that a zero-radiance input always produces a zero-volt output without the complication of a fast radiation chopper. It works by serving the output to zero during each backscan while the detectors are all completely darkened by means of a shutter. Data taken during the active portion of the scan is then measured with respect to this zero reference level. A third feature compensates instantaneous scan angle for up to ± 5 degrees of aircraft roll by using a vertical gyro to correct the scanner's time-base.

Papers published to date on the CAR are as follows:

1. King, M. D., P. V. Hobbs, and L. F. Radke, 1987: Determination of Uncertainty Parameters of Clouds from Airborne Measurements of Scattered Radiation Within Clouds, Proc. Beijing Intl. Rad Symp., Beijing, PRC.
2. King, M. D., M. G. Strange, P. Leone, and L. R. Blain, 1986: Multiwave Scanning Radiometer for Airborne Measurements of Scattered Radiation Within Clouds, J. Atmos. and Oceanic Tech., 3, 513-522.
3. King, M. D., 1981: A Method for Determining the Single Scattering Albedo of Clouds Through Observation of the Internal Scattered Radiation Field, J. Atmos. Sci., 38, 2031-2044.
4. Radke, L. F., M. D. King, and P. V. Hobbs, 1986: Preliminary Measurements of the Cloud Single Scattering Albedo and Interstitial Aerosol from an Aircraft, Proc. Ninth Intl. Cloud Phys. Conf., Tallinn, Estonia, USSR.

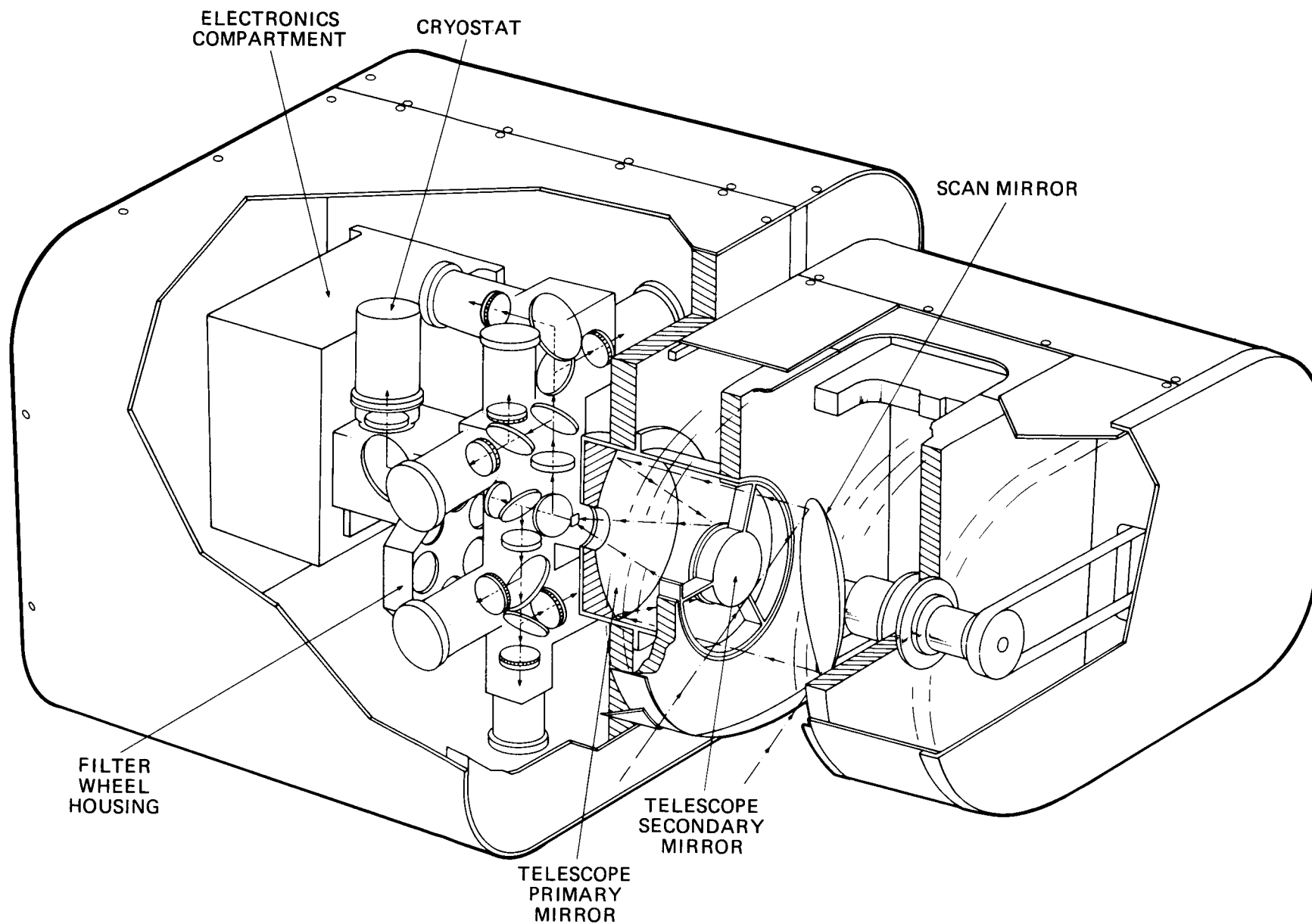


Figure 1. Cutaway drawing of the internal optics of the CAR

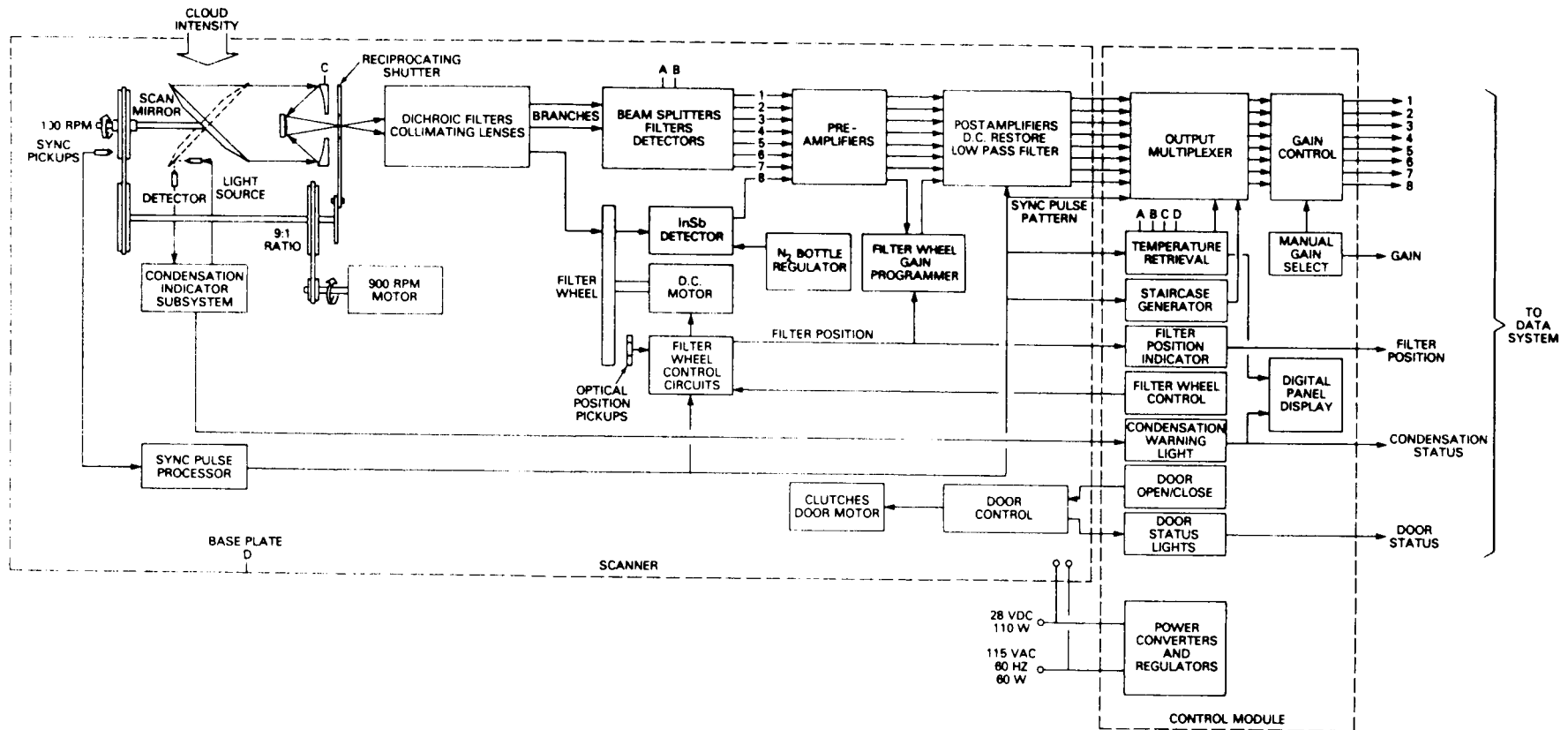


Figure 2. Block Diagram of the electronics of the CAR

DATA UTILIZATION

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The Laboratory For Oceans Computing Facility

by

R. Kao (670.1)

The first VAX computer in the Laboratory for Oceans Computing Facility (LOCF) was installed in April 1986 and the facility has been largely expanded since then. The growth is not only in hardware and software, but also in the number of users and in supporting R & D projects. The LOCF serves as a general purpose computing facility for Code 670 projects. These are: ocean color research projects, sea ice research projects, processing of the Nimbus-7 Coastal Zone Color Scanner data set, real-time ingest and analysis of TIROS-N satellite data, study of the Synthetic Aperture Radar data, study of LANDSAT data, and many others.

The physical space and the electrical power layout of the computing room were modified to accommodate all the equipment. The facility now has one VAX-11/750 computer, three MicroVAX II computers, and a variety of peripherals. All the computers are 'clustered' using Local Area VAXcluster technology of Digital Equipment Corporation for resource sharing such as sharing local disk drives and line printers. All the computers are also on the SPAN network so that information exchanges with outside communities are convenient. The system configuration diagrams are shown in Figures 1 and 2. Currently, we are in the process of connecting Code 670 investigators' IBM personal computers to the network. This provides a rapid means of accessing data on the

LOCF computers.

The LOCF has several image processing stations which include two International Imaging Systems (IIS) model 75 processors and one Adage processor. An IIS IVAS image processing workstation is on order. The facility now has disk farms of the capacity of 7.6 GBytes and more disks will be added to the system. Additionally, the LOCF has Sony optical disk drives for large data set storage and archival.

The facility has the capability of ingesting the TIROS-N HRPT satellite data on a real-time basis.

More than 30 software packages have been installed on the systems. System software packages, network software, FORTRAN and C compilers, database management software, image processing software, graphics, mathematics and statistics packages, TAE, Catalog Manager, GEMPAK, LAS and many other software developed on the LOCF computers such as SEAPAK have greatly advanced the capability of the LOCF.

The LOCF coordinates vendors to give either a presentation or a demonstration of their products should there are interest from the user groups. Examples are: Sony optical disks, RCA Domsat capability, INMARSAT communication, IIS image processors, SEICO color copiers, a VHS data tape unit. The facility also arranges courses when needed. A TAE class was held for the LOCF users.

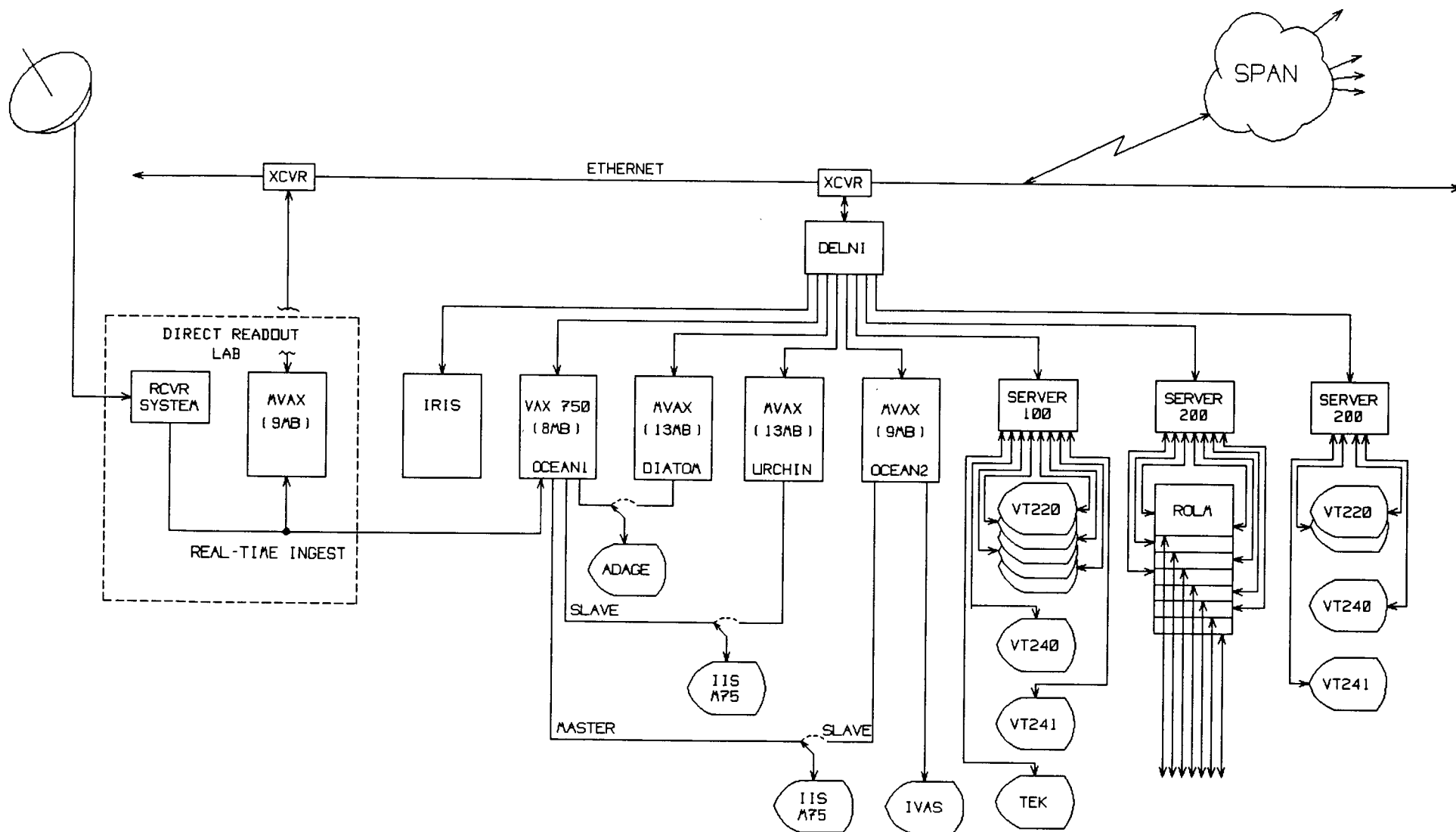


Figure 1. NETWORK CONFIGURATION

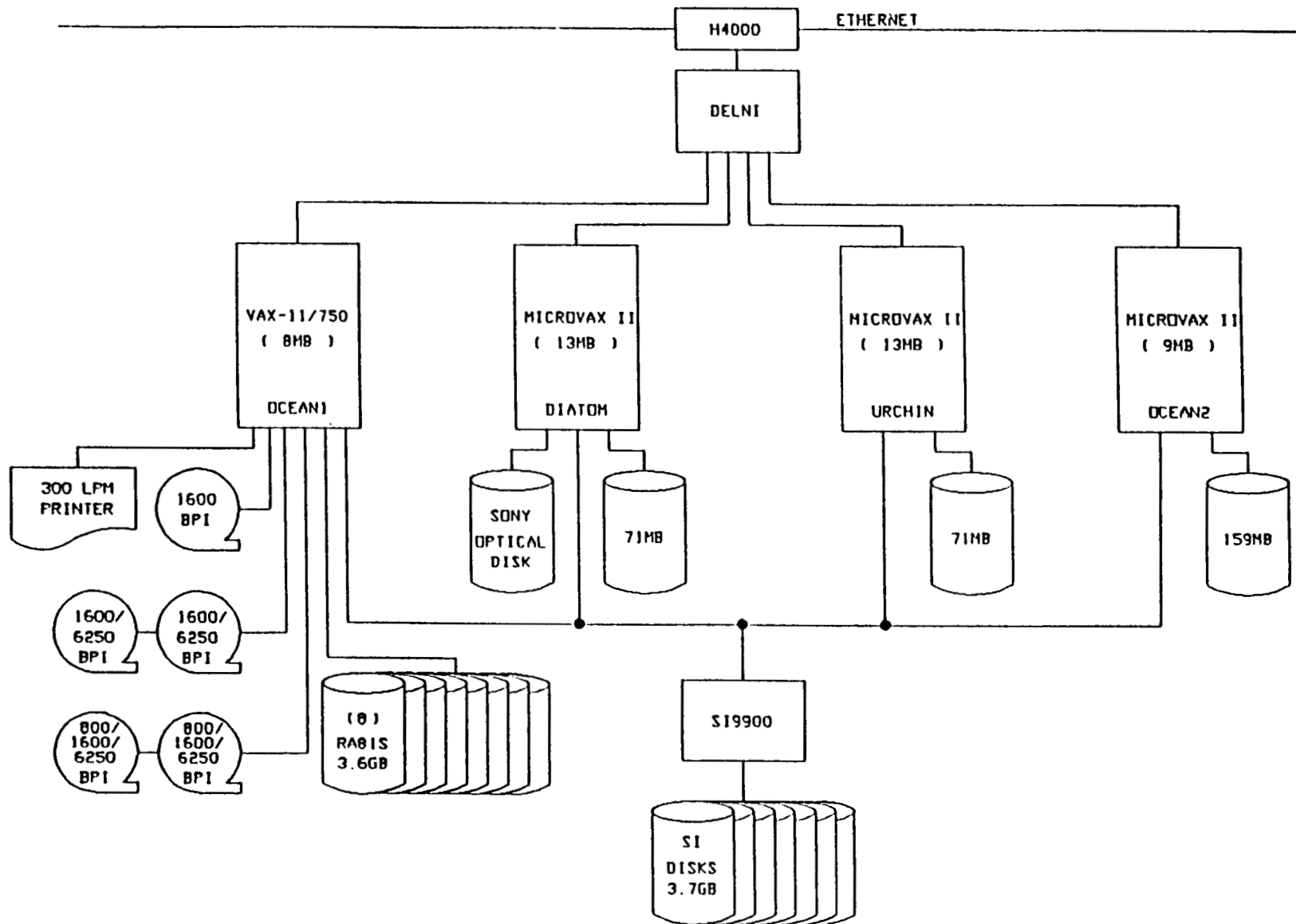


Figure 1. Local Area Vax Cluster

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Code 672 Observational Science Branch Computer Networks

by

D. W. Hancock and H. G. Shirk (672)

In general, networking increases productivity due to the speed of transmission, easy access to remote computers, ability to share files, and increased availability of peripherals. Two different networks within Code 672 Observational Science Branch are described below.

The Observational Science Branch Local Area Network (OSBLAN) supports a Gould PowerNode 6000 super-minicomputer, two Sun workstations, and a PC network consisting of MS-DOS personal computers (Figure 1). OSBLAN uses the Transmission Control Protocol/Internet Protocol (TCP/IP) on Ethernet cabling and is bridged in turn to NFSNET/ARPANET at GSFC via a Proteon gateway machine.

The Gould and Suns run under Unix operating systems that support NFS (Network File Sharing). OSBLAN PC systems use the Sun Microsystems PC-NFS network software for DOS. PC-NFS uses the central-server approach to networking which means that all network PCs share disk space on a central server system, currently the Gould. Users share and exchange files with little effort, and remote logins and file transfers to computers on the network are easily achieved. Output data can be spooled to one of four printers on the OSBLAN. A user does not see the difference between his files being on a local physical hard disk or on the file server disk. The files on the server can be easily

accessed by other users by the permissions given. DOS files can be converted to Unix and Unix files to DOS by provided utilities. Sun local disk files are backed up using the Gould tape unit. The PC local disk can be copied to the Gould and then backed up on 9-track tape. From OSBLAN, users can exchange data with computers on the three major Wide Area Networks (WANs): ARPANET, BITNET, and DECNET. Data to the Division 670 Vax computer at GSFC can be exchanged over the network. NASAMAIL and GSFCMAIL can be sent from any computer on the network. The communication with the WANs uses the Proteon gateway with a 9.6 kilobaud direct line.

A second network, the TOPEX-MORAR Network (TMNet) connects MacIntosh and MS-DOS personal computers (Figure 2). TMNet is configured in an active star topology and was implemented by using the old AT&T phone lines that existed in the E-106 building. The network allows MacIntosh and MS-DOS computers to share disk space, transfer and translate files, and use network output devices. Network output is currently handled by an Apple LaserWriter Plus with a second laser printer on order. The TMNet uses TOPS for its network software and AppleTalk cable connection. TOPS is a distributed server network which means any connected system can be a file server with each user deciding what files to make available on the network. TOPS works transparently, therefore, the network files look like MacIntosh files on the MacIntosh and MS-DOS files on PCs. TOPS comes with translators for the most popular MS-DOS and MacIntosh file formats. In the future, plans are to bridge the TMNet to the OSBLAN by using a Kinetic Fastpath machine.

OBSERVATIONAL SCIENCE BRANCH LOCAL AREA NETWORK SCHEMATIC
BUILDING E-106 WALLOPS FLIGHT FACILITY
WALLOPS ISLAND, VIRGINIA

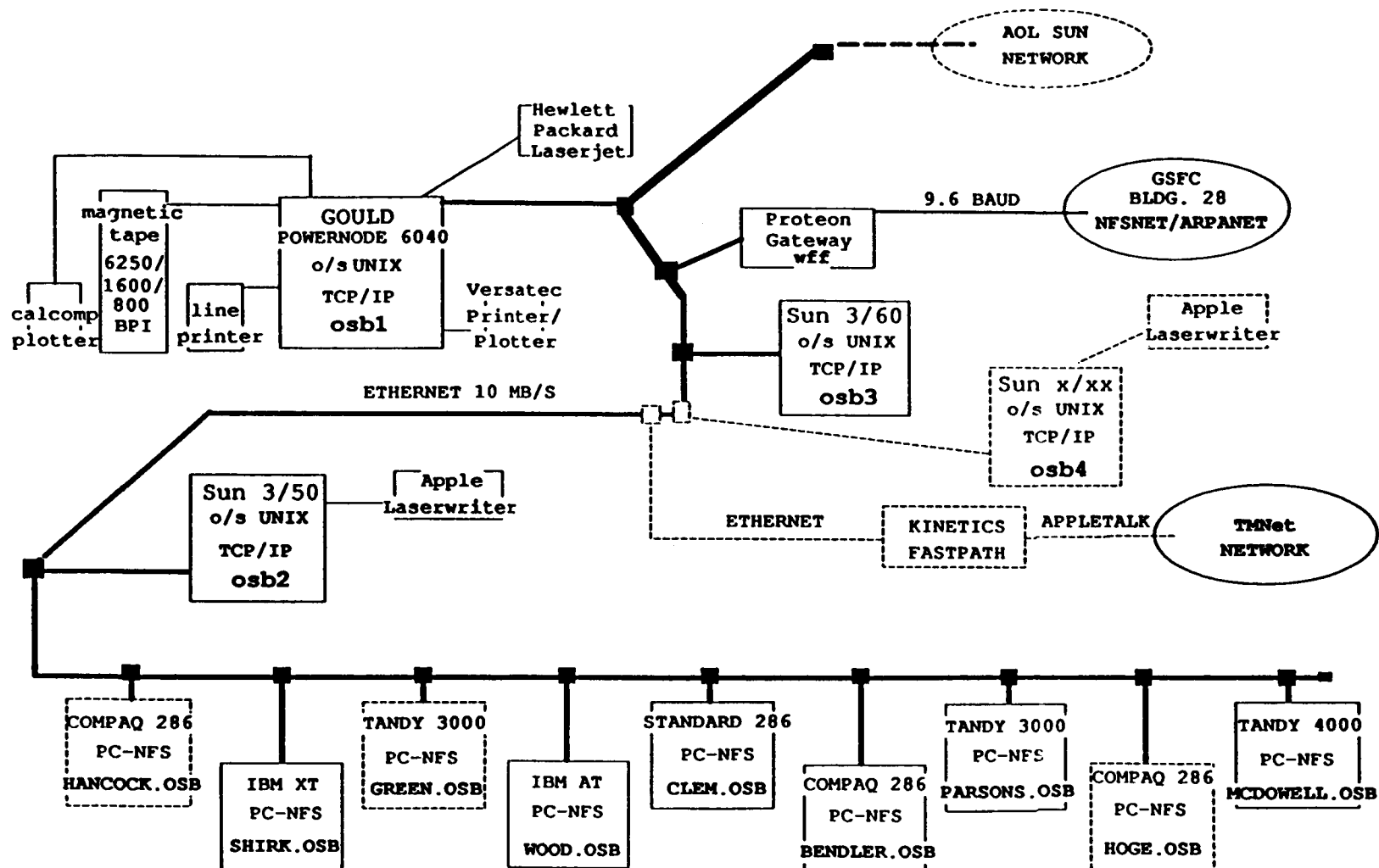


Figure 1.

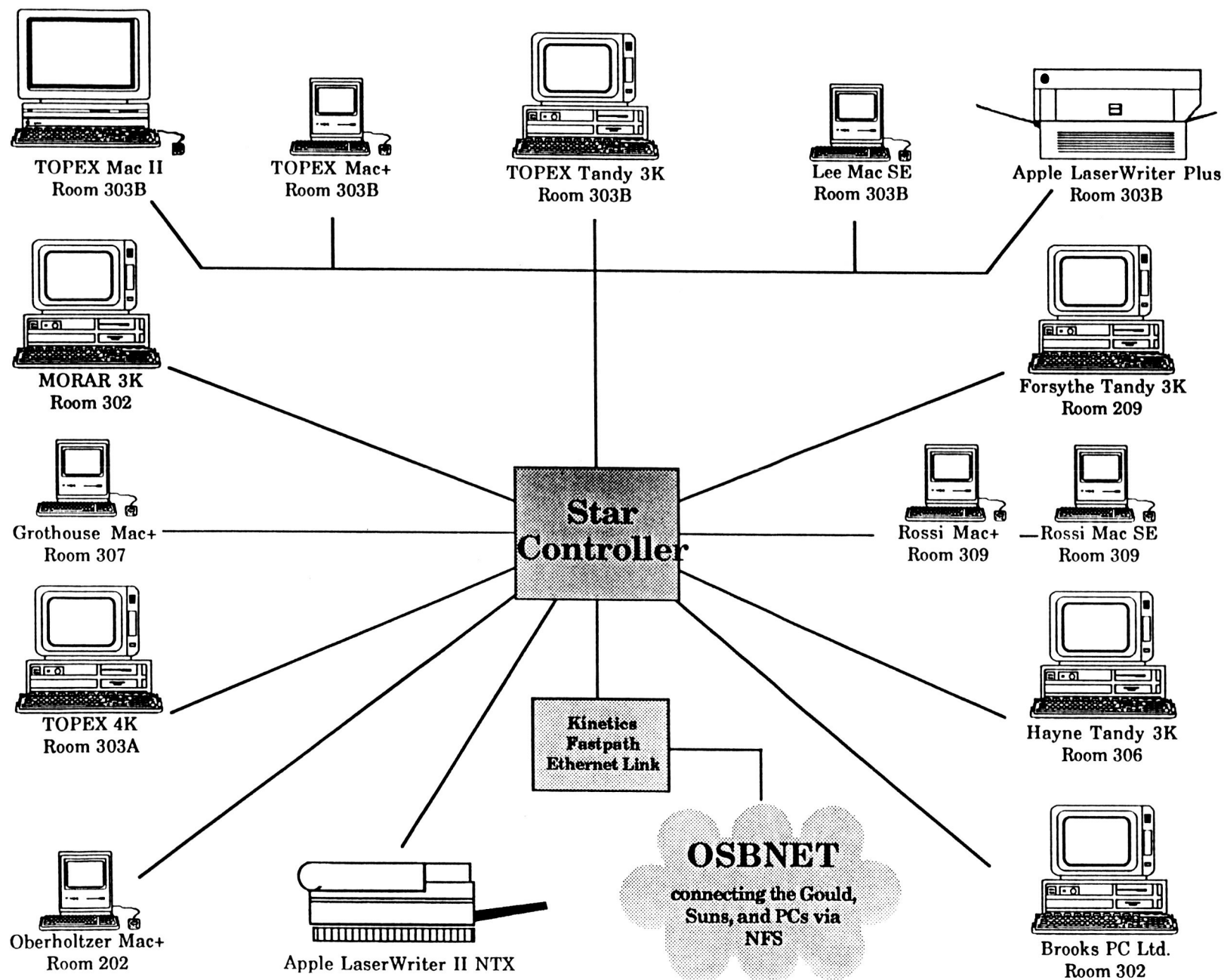


Figure 2.

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Personal Computers on Ethernet

by

R. Kao (670.1)

Many researchers in the Division have projects which require transferring large files between their personal computers (PC) and VAX computers in the Laboratory for Oceans Computing Facility (LOCF). Since Ethernet local area network provides high-speed communication channels which make file transfers (among other capabilities) practical, we have put together a network plan to connect IBM and IBM compatible PC's to Ethernet for participating personnel of Code 670 in building 22.

Our design employs ThinWire Ethernet technology. A simplified configuration diagram is shown in Figure 1. A DEC multiport repeater (DEMPR) is used for connection of ThinWire Ethernet segments. One port of DEMPR is connected to a H4000 transceiver and the transceiver is clamped onto the Goddard Ethernet 'backbone' coaxial cable so that the PC's can be optionally on the SPAN network. All these 'common' elements have been successfully installed and tested.

The components needed for each PC to access the network are: a PC Ethernet controller and communication software. We have put together 'mass' buys for these items and have received all the components. A few PC stations have been connected to the network and have functioned very satisfactorily. In addition to providing fast file transferring between two modes, the software

also supports task-to-task communications, network resource sharing, remote file access, and utilities for network file operations. We are now in the process of stringing cables to connect all other PC stations to the network.

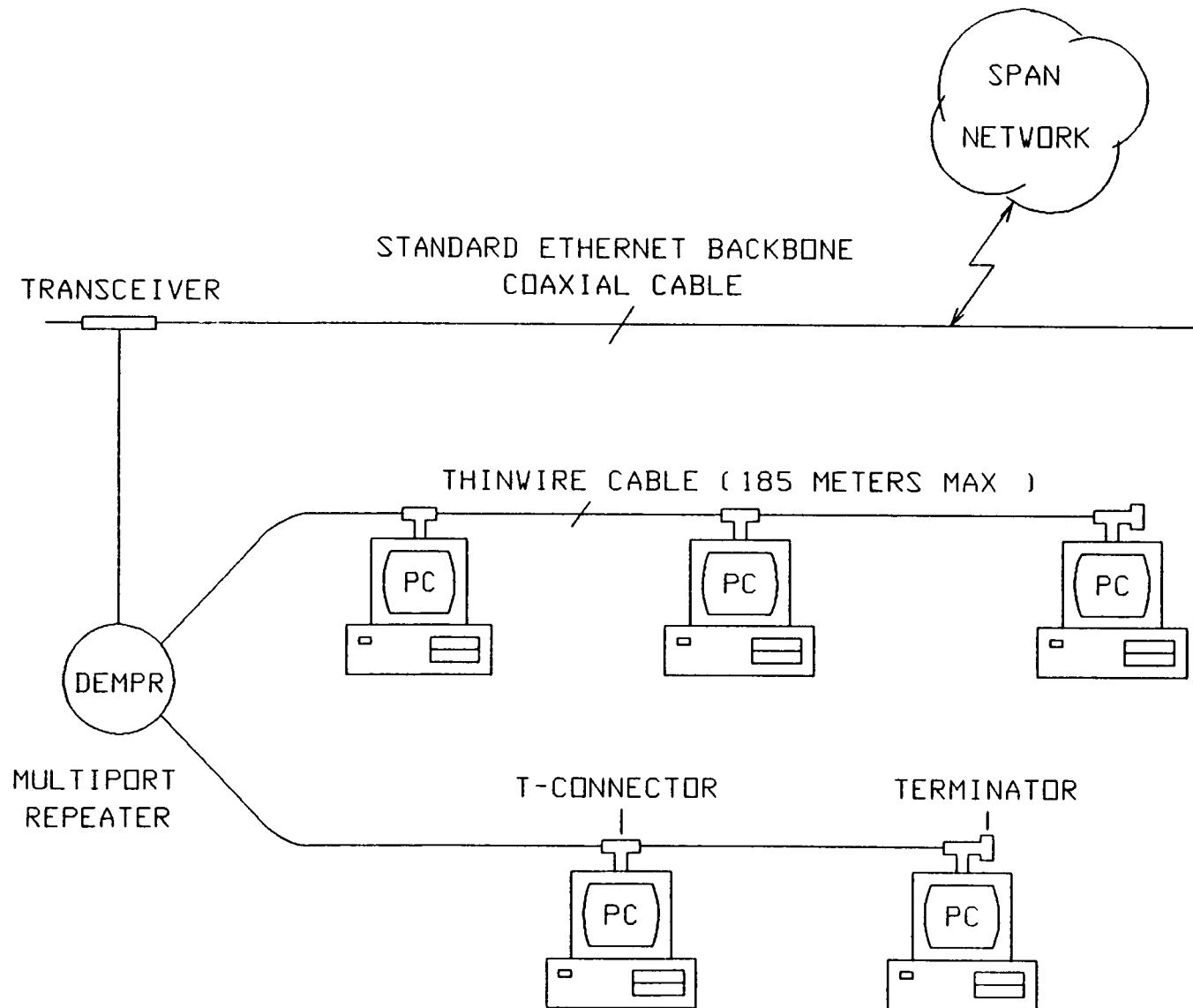


Figure 1. PC-Based Ethernet Configuration

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THIRD INTERNATIONAL SATELLITE DIRECT BROADCAST
SERVICES USER'S CONFERENCE

by

J. Kamowski, C. Vermillion (670.1)

A workshop titled, "The Third International Satellite Direct Broadcast Services User's Conference," jointly sponsored by NASA and NOAA/NESDIS is scheduled to be held June 20-24, 1988, at the International Hotel located at the Baltimore-Washington Airport.

It is anticipated that attendance will exceed 400 persons from many countries throughout the world. A call for papers has been issued, with responses from Japan, Poland, England, Canada, and Barbados as well as the United States.

Non-contributing associate sponsors include, European Space Agency, Japan Meteorological Agency, U.S. Department of Agriculture, U.S. Agency for International Development, U. S. Geological Survey, and the World Meteorological Organization. It is anticipated that additional sponsors will join, lending their names, distribution facilities, and expertise to the conference.

Well known speakers have consented to address the audience from such organizations as, NASA Headquarters; Department of Commerce; NOAA/NESDIS; United Nations; European Space Agency; Japan Meteorological Agency; World Meteorological Organization; United Kingdom; Institute of Meteorology and Water Management; Krakow, Poland; Institute of Industrial Science; University of Tokyo; and

Japan Broadcasting Corporation, Japan; University of Dundee, United Kingdom; Atmospheric Environment Service, and MacDonald Dettwiler, Canada; are but to name a few, in addition to the many U.S. organizations. Mr. Adigun Ade Abiodun, an expert on space applications from the United Nations in New York will be the keynote speaker.

Several manufacturers of satellite related products have exhibited their desires to attend displaying their wares.

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LOW COST REAL TIME INTERACTIVE ANALYSIS SYSTEM

by

F. Stetina (670.1)

Efforts continue, to develop a low cost real-time interactive analysis system for the reception of satellite data. A multi-purpose ingest hardware software frame formatter has been demonstrated for GOES and TIROS data and work is proceeding on extending the capability to receive GMS data. A similar system has been proposed as an archival and analysis system for use with INSAT data and studies are underway to modify the system to receive the planned SeaWiFS (ocean color) data. This system has been proposed as the core of a number of international programs in support of U.S. AID activities. The following systems have been delivered or are nearing final testing:

- o NOAA-SOCC -for the analysis of TIROS instrument performance
- o GSFC-(612) -real time GOES reception for severe storms research
- o U.S. AID
Fiji Islands-GMS real time reception for disaster warning system in Southwest Pacific
- o U.S. AID
Bangladesh -Agro-Climatic and Economic Development Program

Systems under development

- o NSF/NOAA/NASA-INSAT data archival and analysis system
- o NASA/EOSAT -Real time reception of Seawifs ocean color data
- o EOS/NASA -Studies have been initiated for a real time system for EOS polar platform research data.

Software Development:

A substantial amount of work has been directed toward improving software application programs; these have been in support of the Bangladesh and Fiji science applications training activities and include: Agro-Meteorology, Hydrology, Meteorology (Severe Storms and TOVS) and Satellite Oceanography.

In addition, important software packages have been received from the National Weather Service (SLOSH) and the Federal Emergency Management Agency (IEMIS), and are being integrated into existing software systems to become the basis of a disaster warning and economic development program spatial analysis and modeling system for Third World countries.

This software development activity will be directly applicable to the development of Eos data systems and data exchange programs involving the use of Eos real time data from the international community.

INSTRUMENTATION

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NAVIGATIONAL AND ENVIRONMENTAL MEASUREMENT SYSTEM (NEMS)

by

T. D. Clem (672)

The NEMS concept and design were initiated from the need to measure and record positional and environmental information during aircraft flights of developmental science research instrumentation. The unit was designed as a stand-alone system which could serve the needs of instruments whose developmental nature did not justify the cost and complexity of including these measurements within the instrument data system. Initially, the system was comprised of a Loran-C receiver and a portable IBM compatible computer recording position and time. Later, the system was interfaced with the Wallops aircraft inertial navigation system (INS), and various other sensors were supplied and shared by the Goddard science users. Initial development was supported by various Code 600 users. During 1986 and 1987, the Wallops Aeronautical Programs Branch (Code 831) supported development and equipment purchases. Real-time position mapping on video monitors was added for investigator's use and information. In 1987, the use of a Global Positioning System (GPS) receiver was included in some missions.

General System Description

Figure 1 shows a total configuration of the system and the various sensors which can be incorporated. These sensors are added or deleted as required for a particular mission. The

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system and sensors are a single stand-alone unit moved from aircraft to aircraft as required. The following information is among that which can be sensed and recorded by the system:

- 1) Time - GMT or Local
- 2) Aircraft Latitude and Longitude Loran-C
- 3) Aircraft Latitude and Longitude from the aircraft INS
- 4) Aircraft Latitude, Longitude, and Altitude from GPS
- 5) Aircraft ground speed
- 6) Aircraft Flight track
- 7) Aircraft (or instrument) roll and pitch angle
- 8) Outside total air temperature
- 9) Outside air pressure (with standard altitude calculated)
- 10) Outside air dew point
- 11) Nadir thermal irradiance
- 12) Vertical acceleration

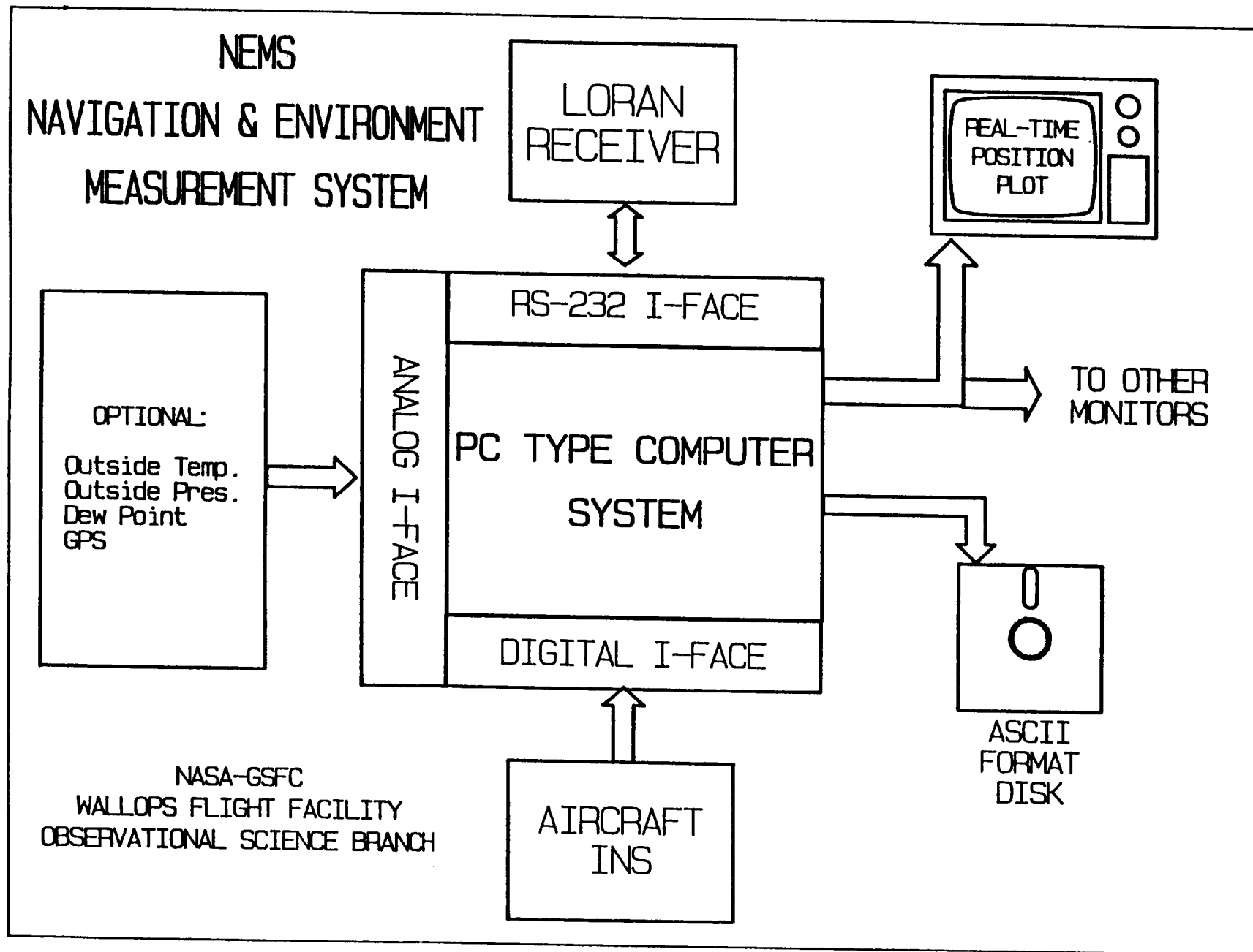


Figure 1.

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AIRBORNE LIDAR GLOBAL POSITIONING INVESTIGATIONS

by

W. B. Krabill (672)

The Global Positioning System (GPS) network of satellites shows high promise of revolutionizing methods for conducting surveying, navigation, and positioning. This is especially true in the case of airborne or satellite positioning. A single GPS receiver (suitably adapted for aircraft deployment) can yield positioning accuracies (world-wide) in the order of 30 - 50 m vertically, as well as horizontally. This accuracy is dramatically improved when a second GPS receiver is positioned at a known horizontal and vertical reference. Absolute horizontal and vertical positioning of 1 to 2 meters are easily achieved over areas of separation of tens of kilometers. If four common satellites remain in lock in both receivers, then differential phase pseudo-ranges on the GPS L-band carrier can be utilized to achieve accuracies of +/- 10 cm and perhaps as good as +/- 2 cm.

The initial proof of concept investigation for airborne positioning using the phase difference between the airborne and stationary GPS receivers was conducted at the NASA/GSFC/Wallops Flight Facility (WFF) by scientists from the NOAA National Geodetic Survey (NGS) and the Airborne Oceanographic Lidar (AOL) group. The single flight experiment was conducted in August 1986 over the Chincoteague Bay located near WFF. The precise laser ranging capability of the AOL system was used to measure the relative accuracy of the aircraft height determined from tracking

the phase differences between the stationary and aircraft mounted GPS receivers. The GPS ellipsoid height estimates are shown compared on a gross scale with the AOL altitude measurements in figure 1. An expanded view of a portion of the comparison is shown in figure 2 after removal of the obvious bias in figure 1. The results from the flight experiment demonstrated that relative decimeter positioning is already achievable.

Following these initial investigations with aircraft GPS receivers, two Motorola Eagle GPS receivers were obtained by the Laboratory for Oceans and Ice. The Eagle receivers have an improved once per second update rate compared to the once per three second update rate of the TI receivers used in the earlier NASA/NOAA flight tests. Within a few days of receiving the GPS units, they were deployed in the NASA Arctic Ice Experiment conducted during May 1987. During this experiment, both of the receivers were operated as airborne units and used to ensure that the aircraft remained within ± 1.5 km of the intended flight track so that comparisons with contemporaneous SAR (obtained from a different aircraft) and submarine up-looking sonar observations would be possible. The GPS positional measurements are currently being utilized together with aerial photography to register the independent data sets. Also, the vertical control afforded by the GPS receivers is being used to remove aircraft vertical motion from the laser profiling record so that detailed ice topographic features can be statistically analyzed. A section of the ice topography is shown in figure 3 where first year and multi-year ice with obvious ridging can be seen.

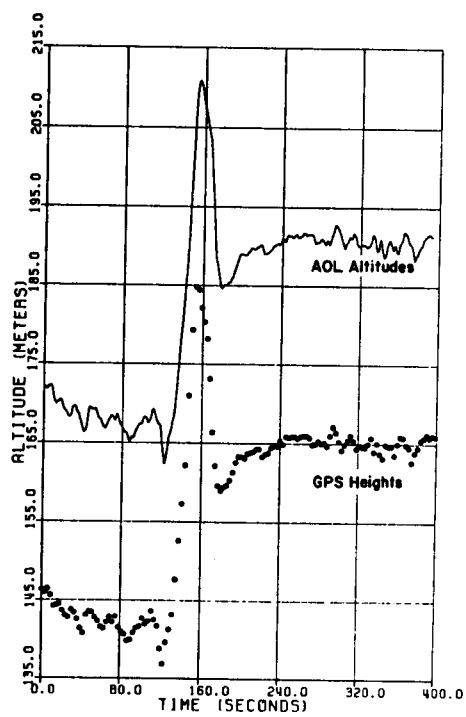


Figure 1.

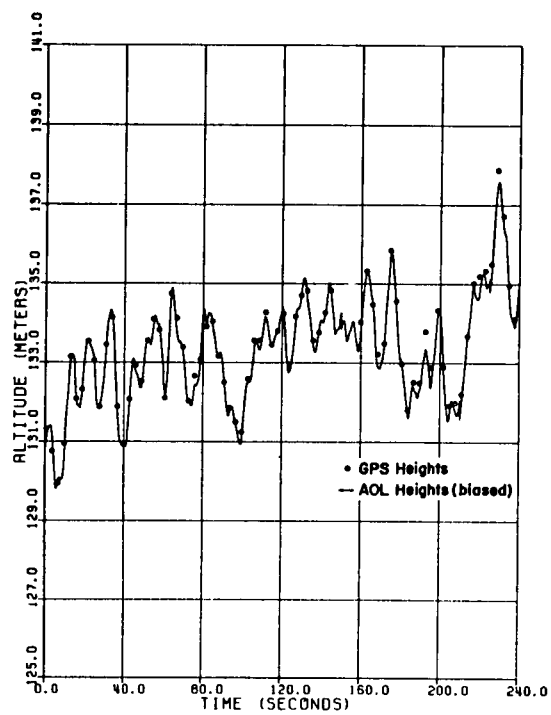


Figure 2.

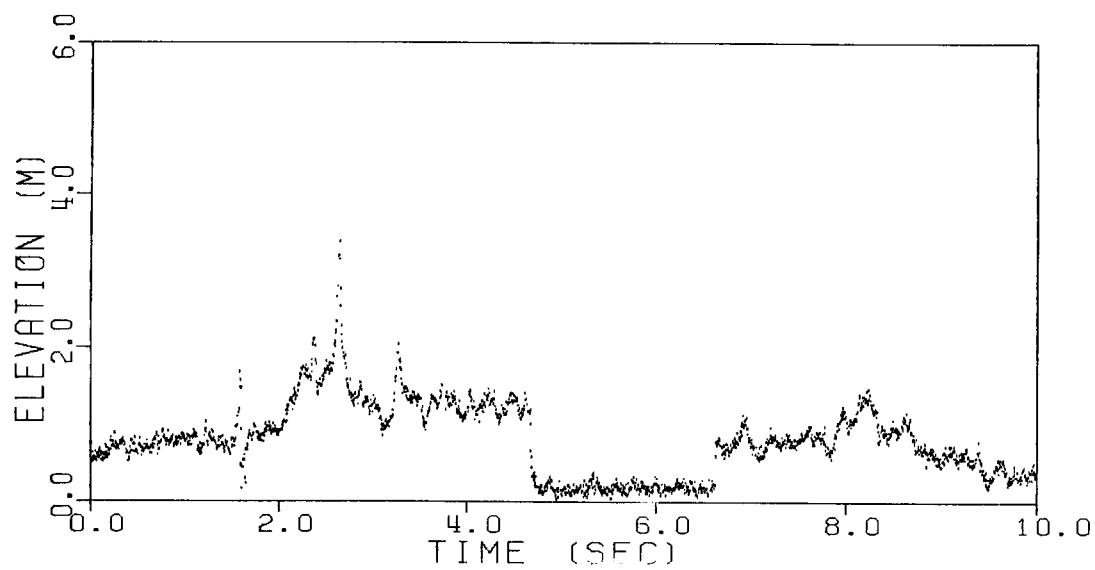


Figure 3.

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MICROWAVE REMOTE SENSING OF SOIL MOISTURE

by

J. C. Shiue and J. R. Wang (675)

Knowledge of soil moisture is important to many disciplines, such as agriculture, hydrology, and meteorology. Soil moisture distribution of vast regions can be measured efficiently only with remote sensing techniques from airborne or satellite platforms.

At low microwave frequencies, water has a much larger dielectric constant than dry soil. This difference manifests itself in surface emissivity (or reflectivity) change between dry and wet soils, and can be measured by a microwave radiometer or radar.

The Microwave Sensors and Data Communications Branch is developing microwave remote sensing techniques using both radar and radiometry, but primarily with microwave radiometry. Our efforts in these areas range from developing algorithms for data interpretation to conducting feasibility studies for space systems, with a primary goal of developing a microwave radiometer for soil moisture measurement from satellites, such as Eos or the Space Station. A proposal to develop a synthetic aperture radiometer for soil moisture observation from Eos polar platform is being prepared from our group. (See separate element under ESTAR by D. Levine)

We started in soil moisture research by making truck-based measurements of emissivities of bare and vegetation covered

agricultural fields to establish the basic algorithms for data interpretation. We studied the synergistic aspects of soil moistures as measured by both an L-band microwave radiometer (LBMR) and an L-band synthetic aperture radar (SAR) from the Space Shuttle. We also conducted airborne experiments of soil moisture with an LBMR in the Eastern Shore of Maryland, western high plains of Texas, and southern France (HAPEX)*. We studied (in cooperation with Hughes Aircraft and G.E.) the feasibility of building an LBMR with a 10 meter real-aperture, electronically scanning array.

In 1987, we participated in the FIFE** remote sensing experiment over the Konza Prairie in Kansas, and made a time series measurement of the area's soil moisture changes with an LBMR from aboard the NASA C-130. We are processing and analyzing the data from the flight experiments. Figures 1 and 2 are some preliminary results from the FIFE flights. Figure 1 is a comparison between soil moistures retrieved from the airborne LBMR to soil moistures obtained from direct in-situ probes. This figure establishes that, except for a small bias, the retrieved soil moisture correlates very well with the ground truth, showing the maturity of this observation technique. The real power of this technique is in its ability to map areal distribution of soil moisture. Figure 2 shows soil moisture contours of a small water shed, about 1 km by 1.5 km in size. The data represent a saturated soil moisture condition, shortly after a storm.

We will be back to flying over the Konza Prairie again in 1988 to study the change in emissivity of the area, after some part of the Konza's grassland is burned as a part of the special research treatment. During May of 1988, J. R. Wang will be participating in an aircraft experiment to study the use of synthetic aperture radars to measure soil moisture and vegetation of agricultural fields in the San Juanquin Valley of California.

* : HAPEX = Hydrologic and Atmospheric Pilot Experiment
** : FIFE = First ISCLSCP*** Field Experiment
*** : ISCLSCP = International Satellite Land Surface Climatology Program

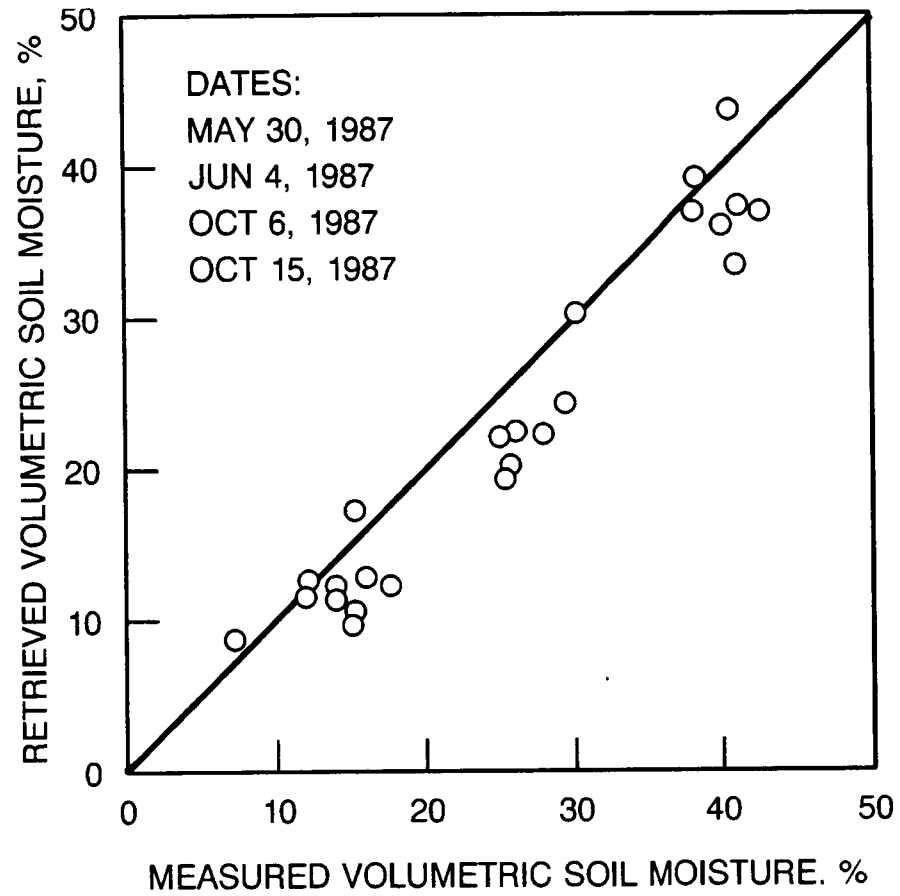
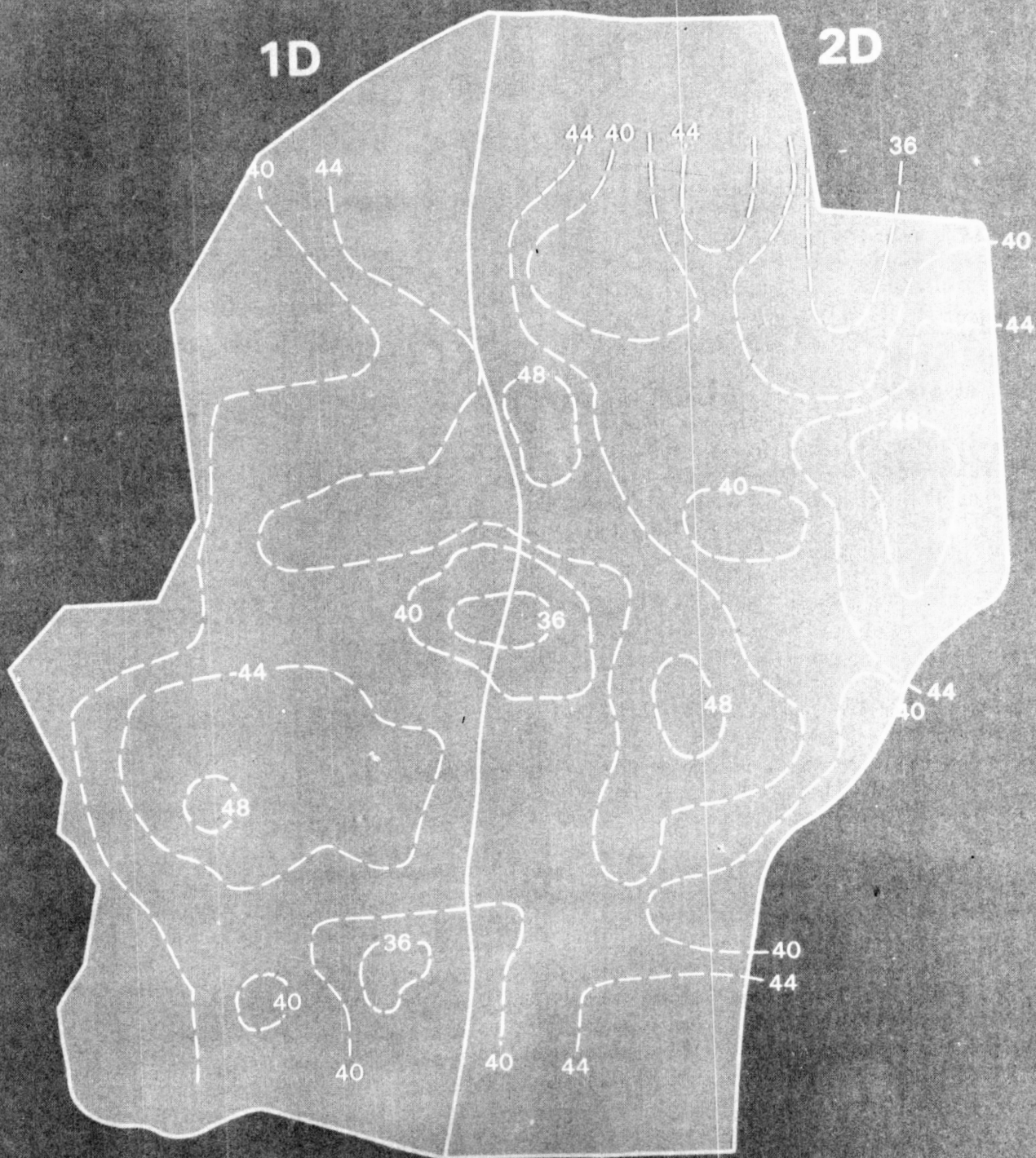


Figure 1.

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SOIL MOISTURE DISTRIBUTION

Figure 2.

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SYNTHETIC APERTURE MICROWAVE RADIOMETER

by

D. M. Le Vine (675)

Realizing the full potential of microwave remote sensing from space requires putting relatively large antennas in orbit. For example, in order to measure soil moisture, an important element in the global hydrologic cycle, an antenna on the order of 20 meters on a side would be required in space as part NASA,s Earth Observing System (Eos). Research is being conducted to develop synthetic aperture antennas to reduce the physical collecting area required of sensors in space, and to possibly open the door to new applications of microwave remote sensing.

The technique under investigation involves using a correlation interferometer with multiple baselines and is similar to "earth rctation synthesis" developed in radio astronomy. In this procedure the product of the voltages from a pair of antennas is measured coherently (amplitude and phase are detected). This correlation is proportional to the Fourier spectrum of the scene evaluated at a frequency which depends on the spacing between the antennas. By making measurements at many spacings, one can "map" the spectrum, and then the scene itself can be obtained by taking the inverse Fourier transform. The important consideration for remote sensing purposes is that the resolution obtained depends on how well the Fourier spectrum has been sampled (i.e., on the distribution of baselines at which measurements have been made) and not on the size of the antennas actually employed in these

measurements. Thus, one can use small antennas with measurements at many baselines and achieve the resolution of a single antenna with a much larger aperture.

The Microwave Sensors and Data Collection Branch has been engaged in research to develop this technique for applications to remote sensing of soil moisture from space. Soil moisture is important for agricultural applications and for understanding the global hydrologic cycle.

We now have an aircraft prototype of an instrument suitable for making such measurements. This is an L-band radiometer called "ESTAR" which we hope will become part of the Earth Observing System (Eos). ESTAR is a hybrid instrument which uses both real aperture antennas (long sticks to obtain resolution in the along-track dimension) and aperture synthesis (correlation between sticks to obtain resolution in the cross track dimension). The hybrid was chosen as a compromise to increase the sensitivity (T) of the instrument.

ESTAR made its maiden flight in February 1988, aboard the NASA P-3 out of Wallops Flight Facility. We hope to be making soil moisture measurements over test fields by the end of the Summer 1988.

This research is a cooperative effort involving the Goddard Space Flight Center, the Microwave Remote Sensing Laboratory at the University of Massachusetts and the Hydrology Laboratory of the U. S. Department of Agriculture.

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RADAR SCATTERING AND SOIL MOISTURE

by

D. M. Le Vine (675) and P. O. Neill (624)

Research is being conducted on microwave scattering from vegetation. The objective is to develop techniques for measuring parameters of the vegetation canopy (such as biomass) needed for understanding global biogeochemical cycles and to develop techniques for correcting microwave measurements of soil moisture for the effects of the vegetation canopy. Measurements of vegetation and soil moisture are important for understanding the environment on a global scale. For example, moisture in the soil is an important, highly variable, element in the global hydrologic cycle. The hydrologic cycle, in turn, is strongly coupled to weather and climate through moisture (and energy) fluxes at the surface. The amount and distribution of vegetation is an important element in biogeochemical cycles; and knowledge of both the vegetation canopy and soil moisture is of practical importance in agricultural management.

This research is a cooperative effort involving the Microwave Sensors and Data Communication Branch (Code 675) and the Hydrological Sciences Branch (Code 624) at Goddard and the Hydrology Laboratory at the U. S. Department Agriculture and the Department of Electrical Engineering at the George Washington University. Significant progress has been made in developing theoretical models for propagation and attenuation in the

vegetation and this theory is being tested using microwave radars and radiometers at specially prepared fields at the nearby USDA Research Center in Beltsville, Maryland.

The theoretical work is based on a discrete model for the vegetation. In this approach, the vegetation is modelled as a random collection of individual objects (e.g., leaves and stems) and the solution is expressed in terms of the scattering amplitude and the location and orientation of the individual objects. The approach depends on having accurate models for the scattering amplitude of the individual objects but has the advantage that the results are expressed in terms of quantities such as plant geometry and orientation statistics which are easily related to the biophysical parameters of the individual plants. The Goddard research team has had significant success using rods and disks to model the plant parts (leaves and stems) and employing a distorted Born approximation to treat the multiple scattering problem. Inversion algorithms for the plant parameters have recently been developed using these solutions.

The experimental work is designed to test the theory and verify the inversion algorithms. This is being done with a three frequency radar (L- C- and X-band) which makes measurements at several polarizations (HH, VV and HV) as a function of incidence angle. This radar was designed for GSFC by the Texas A & M University and is in its first season of operation. The crop most studied to date has been soybeans. Studies have been made

to determine plant geometry and orientation statistics needed for the models and microwave radiometric measurements have been made over the canopy and are being compared with theory. Combined radar and radiometric measurements are being prepared for the coming season (Summer 1988).

ADVANCED SOLIDSTATE ARRAY SPECTRORADIOMETER

by

F. G. Huegel (674), J. Irons (623)

During the Summer of 1987, the Advanced Solidstate Array Spectroradiometer (ASAS) was installed and flown on the NASA Ames C130 in support of the First International Field Experiment (FIFE) missions. The study site was over the grassland areas of the Konza Prairie in Kansas. The data collected with ASAS during these flights has been used to produce the first nearly simultaneous multiangular/multispectral images of selected terrestrial study sites. This data will be valuable in the study of surface bidirectional reflectance and albedo. The data will also be useful for the development of data analysis algorithms for future spaceborne instruments such as the Goddard MODIS-T and JPL's HIRIS.

The ASAS is an airborne imaging spectrometer with 30 spectral channels extending from 450 to 880 nm. The sensor is capable of pointing up to 45 degrees fore and aft of nadir during flight. A conceptional drawing of the ASAS optical system is shown in Figure 1. The reflected solar radiance from a line of 512 pixels at right angles to the aircraft direction of flight is imaged by the collecting optic onto the entrance slit of a spectrometer. Located at the focal plane of the spectrometer is a 512 X 32 element silicon CID detector array. Thus, each of the 512 surface pixels is dispersed into 32 spectral channels. The ASAS image is

formed in the pushbroom fashion. This has the advantage of essentially no moving parts and the dwell time for each pixel is (in this case) at least 512 times greater than can be achieved with a scanning system having a single detector element. The field of view is 25 degrees and the IFOV is 0.85 mr.

Originally, the ASAS sensor was mounted on a baseplate in a fixed nadir viewing position. In 1985, a pointable mount for the sensor was developed at GSFC that allows the ASAS to view an area on the surface at several angles fore and aft of nadir during a single airborne overpass of the site. The ASAS sensor and a color video camera are boresighted on a gimballed platform that is driven by a DC motor via a worm gear and worm wheel as shown in Figure 2. Typically, the target site is imaged at seven angles starting at +45 of nadir and ending at -45 with images acquired at 15 degree increments. The image size is typically 512 elements by 300 scan lines.

In preparation for the FIFE flights, in 1987, a major effort was initiated to redesign and rebuild most of the ASAS sensor electronics. This was done to improve the stability of the array radiometric response and increase the reliability of the instrument. As a result of this effort the instrument operation was trouble free for the entire five months and 23 flights that it was in operation on the C130 and the instrument radiometric stability was on the order of 0.3%. Additional flights of the ASAS are planned for the summer of 1988 over forest areas in Minnesota.

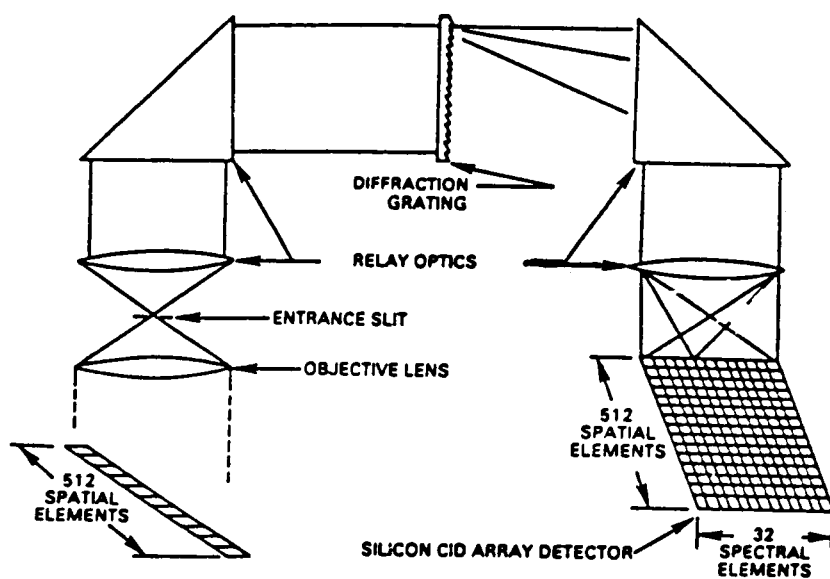


Figure 1. ASA Optical Concept

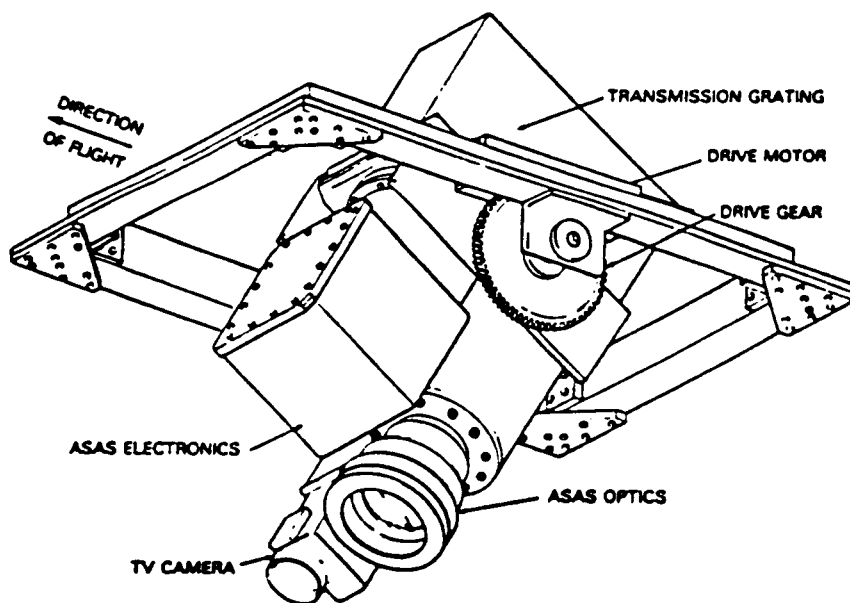


Figure 1. ASA Sensor

AGRICULTURE MULTIBAND EXPERIMENT RADIOMETER

by

W. H. Jones (674), J. Schutt, B. Holben (623)

Agriculture Multiband Experiment Radiometer (Amber) was designed and built in 1979-80 and deployed in 1981. It consists of 15 independent radiometers, 10 with silicon detectors and 5 with lead sulfide detectors. The spectral range of the instrument is from 250 to 2500 nanometers. The 15 collimators are mounted parallel to one another and are contained in a rectangle of 5 by 18 inches. Amber is suspended from a boom which is mounted on a pick-up truck. Amber was designed to simultaneously measure sunlight reflected from vegetation in 15 optical bands. In 1982, program interest shifted from ground truth to satellite image reduction and Amber was retired. Early in 1987, the project scientists concluded that Amber, because of its 15 simple and independent optical systems, would be ideally suited to study polarized light.

The following changes were made to add polarimeter capability to the instrument:

- (1) Amber was designed to down at vegetation, within 45 degrees of the vertical. The scientist required upward looking capability as well with near 4 pi steradian coverage. The boom was modified to allow greater than 3 pi steradian coverage.
- (2) The 5 lead sulfide detectors were not required and were removed along with their associated thermoelectric coolers to compensate for the added weight of the boom mechanism.

(3) Five optical filters corresponding to thematic mapper channel 3 (690 nm) and five optical filters corresponding to thematic mapper channel 4 (820 nm) were installed.

(4) Mounts to hold two polarizing filters (one linear and one circular) for each channel were built, and installed with the filters.

(5) Amber has a 24 degree field-of-view. Since the polarimeter is required to look near the sun, a longer collimator was required with a narrower field-of-view. The collimators were extended three inches and the field-of-view reduced to eight degrees.

This work was completed and the instrument deployed in late August of 1987. We supported the field effort through late November. Presently we are:

(1) Designing a shutter mechanism so that the detector dark current can be measured, allowing greater accuracy at low signal levels.

(2) Selecting and installing new preamplifiers with lower offset drift to allow even lower signal levels to be detected.

This summer after the above work is complete, we plan to design an automated data collection system. This system will collect and store the data and electronically transfer data to mainframe computers at Goddard. Next year, the emphasis will be to increase the data acquisition speed of the instrument. Quicker collection of 4 pi steradian data sets is desirable. The capability to use Amber on aircraft will be a follow on requirement.

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DIODE-PUMPED LASER RESEARCH

by

L. Ramos-Izquierdo, J. Bufton (674)
K. Chan¹

The Laboratory for Oceans is currently working on the development of compact laser diode array (LD) pumped Nd:YAG lasers for use in space-based altimetry and ranging. Laser diode-array pumping technology promises to increase the electrical to optical efficiency of solid state lasers by an order of magnitude with a lifetime increase of nearly three orders of magnitude relative to today's conventional flashlamp-pumped laser systems. The small size, efficiency, and ruggedness make LD-pumped solid state lasers ideal for space based applications.

Under SBIR Phase I & II, OSSA RTOP, and OAST RTOP funding, LD-pumped, Q-switched Nd:YAG lasers are being developed by Lightwave Electronics of Mountain View, California. In an in-house RTOP effort, Ken Chan has designed and is currently testing, a novel multiple-pass LD-pumped Nd:YAG laser amplifier¹ to increase the 100 uJ output pulse energy of the Lightwave laser oscillator (Figure 1). Preliminary results have yielded a round trip amplifier gain of about 15% using 7 mJ LD-pump energy. This amplifier gain is mainly limited by the amount of LD pumping energy available and should increase when two new 10 mJ laser diode pump arrays replace the current ones. Analytical results indicate that with, for example, 40 mJ pump energy, a 4-pass Nd:YAG amplifier could amplify the 100 uJ pulse energy to about 6 mJ. A Q-switched oscillator with more than a few 100 uJ output

energy², in combination with the multiple-pass amplifier, should become a practical laser source for remote sensing applications.

As a parallel activity, DDF funding has been recently obtained to investigate the possible use of custom made fiber optic arrays to obtain an efficient optical coupling mechanism between the emitting laser diode-arrays and the target solid state laser material. Fiber optic coupling arrays would allow for the easy manipulation of the spatial emitting pattern of the diode pump sources to match either an end or side pumping laser configuration. For example, a 1 cm by 1 um typical emitting area from a laser diode-array could be coupled into a linear fiber array that terminates in a 1.8 mm diameter circle; an ideal termination for end pumping of laser rods (Figure 2). Use of fiber optic coupling arrays could also allow for the efficient multiplexing of pump sources acting on a given laser rod by isolating the sensitive and bulky laser diodes from the laser rod. This summer both research activities will be merged to demonstrate a laser diode-array pumped, fiber optic coupled Nd:YAG oscillator and amplifier system.

¹Chan, K. "Multiple-Pass Laser-Diode-Pumped Nd:YAG Amplifier: Design," Applied Optics, 26, 3177 (1987).

²Chan, K. "Generation of High-Power Nanosecond Pulses from Laser Diode Pumped Nd:YAG Lasers," Applied Optics, 27, (1988).

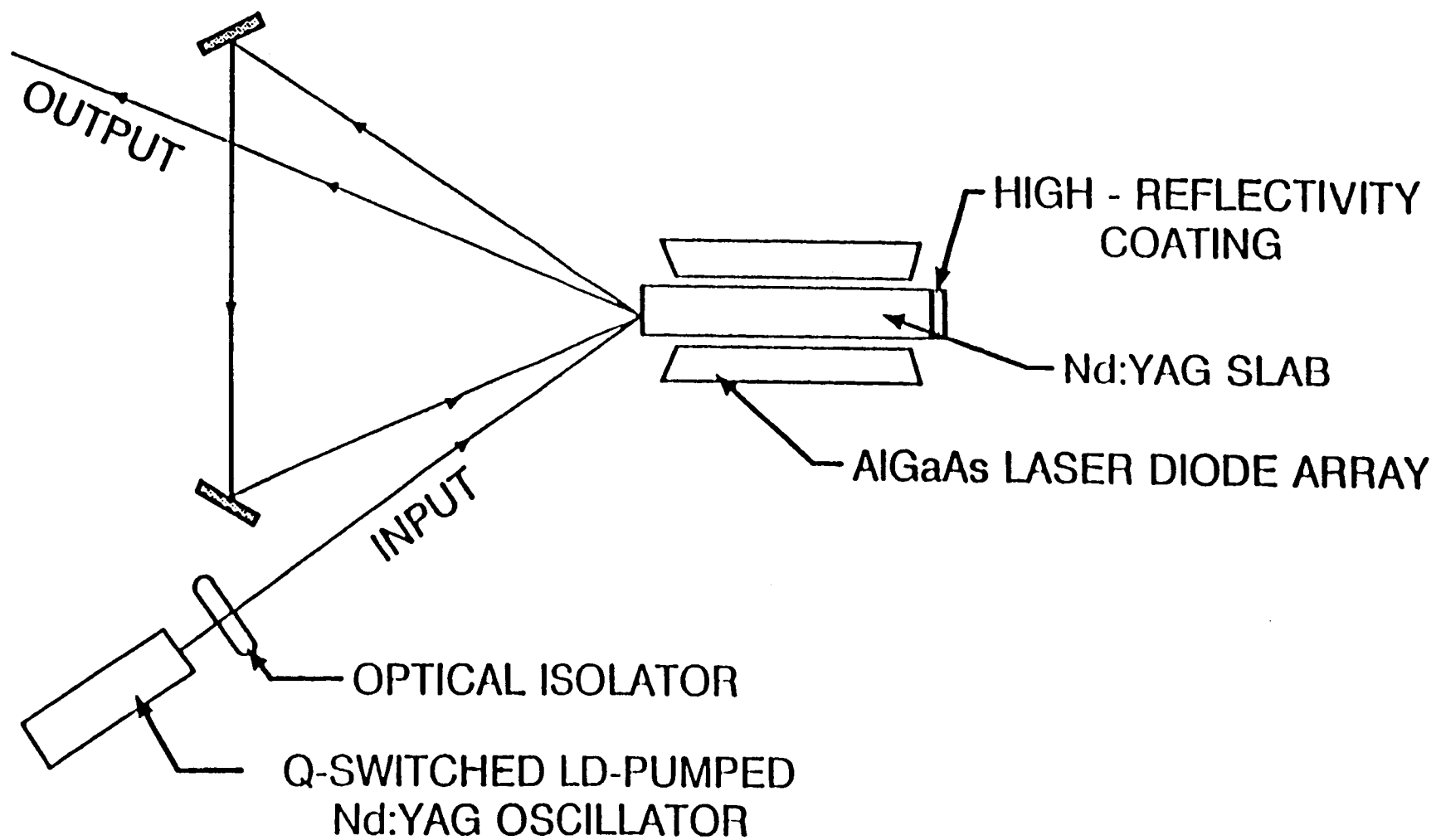


Figure 1. Laser Diode - Pumped Nd:YAG Amplifier

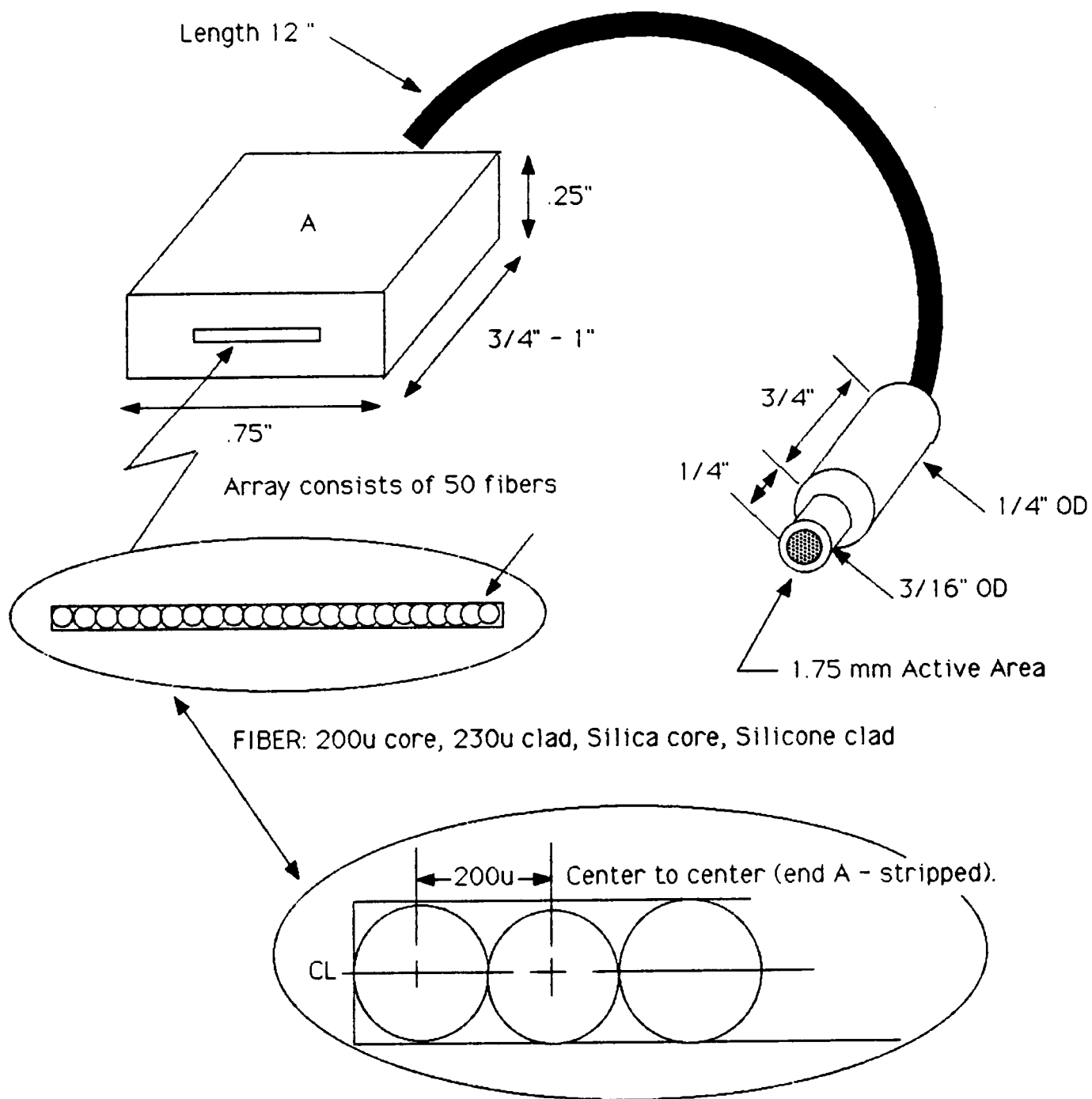


Figure 2. Fiber-Optical Coupling Array

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LARGE APERTURE SCANNING AIRBORNE LIDAR

by

J. Smith (674), R. Bindschadler (671), R. Boers (617),
J. Bufton (674), D. Clem (672),
J. Garvin (622), S. H. Melfi (617)

A large aperture scanning airborne lidar facility is being developed to provide important new capabilities for airborne lidar sensor systems. This complete stand-alone lidar facility is ear-marked to become a semi-permanent system aboard the NASA DC-8 aircraft, contingent upon completion of the proposed airframe modifications (forward nadir viewing port-54" x 63"). Due to the schedule uncertainty for this viewing port installation, the maiden flights will be performed on the NASA P-3 at the Wallops Flight Facility. The already installed bombay hatch on the P-3 will provide a more than adequate nadir viewing portal (80" x 154"). Modest internal aircraft modifications will be required to accommodate the laser optical bench, data and control systems.

The proposed scanning mechanism allows for a large aperture telescope (25" diameter) in front of an elliptical flat (25" x 36") turning mirror positioned at a 45 degree angle with respect to the telescope optical axis. There will be two coincident axes of rotation for the turning mirror; +/- 45 degrees side to side (cross-track) and 0 to 30 degrees fore and aft (along-track) which will allow viewing from the aircraft platform from nadir through 60 degrees forward. Position encoders monitoring both

excursions will provide location information and feedback data for establishing scanning operational parameters. This arrangement will allow aircraft lidar systems to be transformed into a full three-dimensional data-collection facility.

The lidar scanning capability will provide opportunities for acquiring new data sets for atmospheric, earth resources, and oceans communities. This completed facility will also make available the opportunity to acquire simulated Eos lidar data on a near global basis. The ± 45 degree cross-track scanning feature when used aboard aircraft and at sufficient laser firing rates (50Hz) will provide the experimenter with a full 3-D view (mesoscale) of the atmosphere profile. The cross-track scanning capability can also be used to provide surface laser interaction data sets and surface altimetry mapping information. The nadir to 60 degree forward scanning will obtain a tomographic view of the atmosphere, i.e., aerosol profile; a virtual CAT scan of the atmosphere.

The design and construction of this unique scanning mechanism presents exciting technological challenges of maintaining the turning mirror optical flatness during scanning while exposed to extreme temperatures, ambient pressures, aircraft vibrations, etc. The proposed drive system will allow the experimenter to select any cross-track scanning sector within the range of ± 45 degrees from nadir and/or along-track sector from nadir to 60 degrees forward. These scanning sectors need not be symmetric

with nadir or any fixed axis. The drive system will also provide combined 2-axes scanning capabilities. That is, while scanning cross-track the mirror may also be simultaneously tilted. This arrangement will, of course, also provide fixed off-axis viewing at any point within the range of both axes.

We are currently completing the design of the scanning mechanism and are also in the process of procuring major system components. We have received \$50K funding to date from the Director's Discretionary Fund in FY88 (\$200K to follow) and anticipating project completion to be around March/April 1989.

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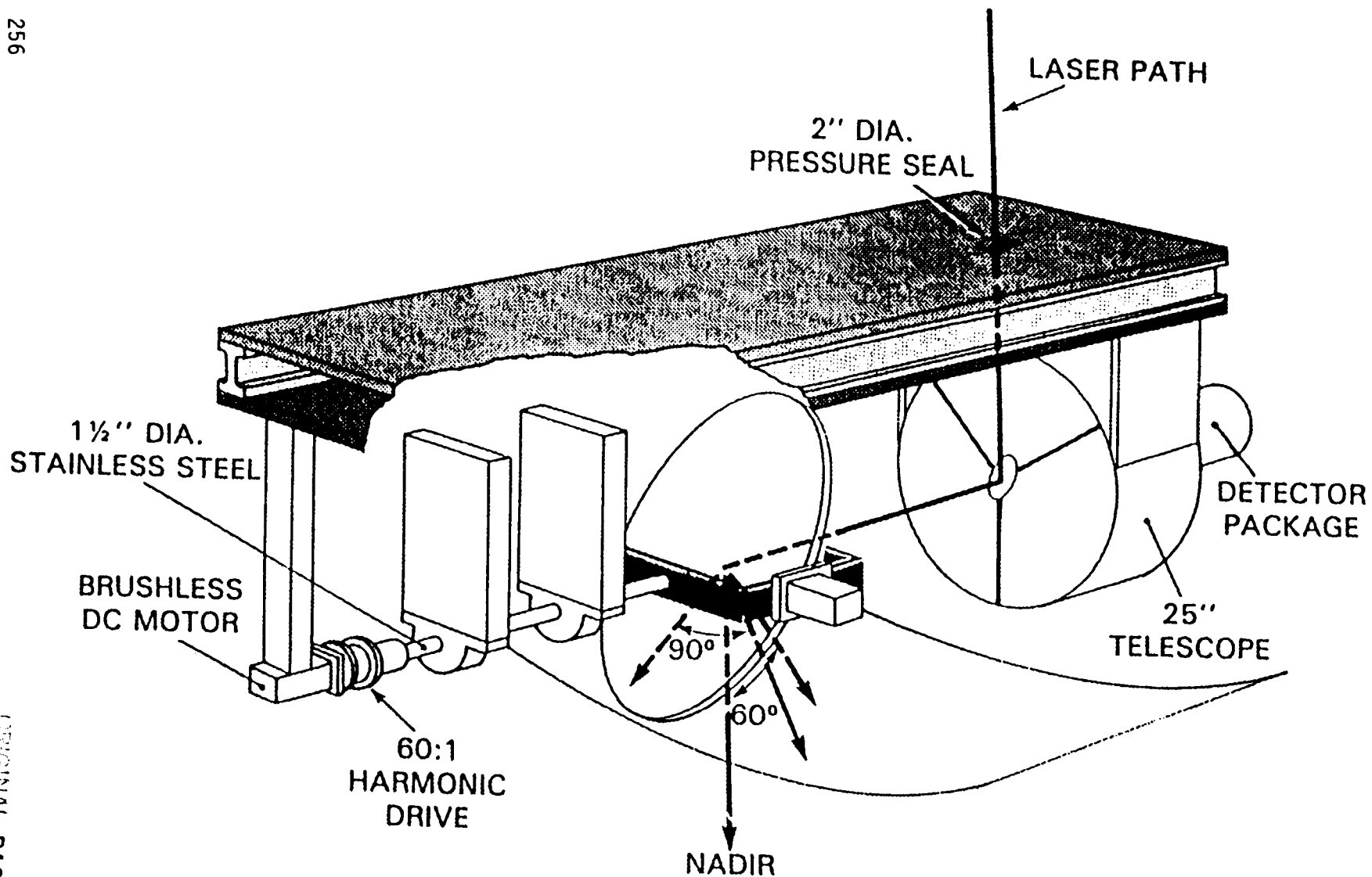


Figure 1. Scanning Lidar Mechanism

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A MULTIPROCESSOR AIRBORNE LIDAR DATA SYSTEM

by

C.W. Wright, S.A. Bailey, G.E. Heath (672), and C.R. Piazza (CSC)

A new multiprocessor data acquisition system has been developed for the existing Airborne Oceanographic Lidar (AOL). This implementation simultaneously utilizes five single board 68010 microcomputers, the UNIX system V operating system, and the real-time executive VRTX. Remote sensing data are collected via CAMAC, GPIB, RS-232, and specialized data sources.

The original data acquisition system was implemented on a Hewlett Packard HP 21-MX 16 bit minicomputer using a multi-tasking real-time operating system and a mixture of assembly and Fortran languages. The constant evolutionary state of the AOL places substantial demands on the real-time data acquisition hardware and software, as well as the post flight data analysis software. As new data sources were added, the original data acquisition software eventually required rewriting in assembly language.

The present collection of data sources produce data at widely varied rates and require varied amounts of burdensome real-time processing and formatting. It was decided in 1985 to replace the aging HP 21-MX minicomputer with a multiprocessor system. Each data source or group of related and compatible data sources would be connected to a single dedicated microcomputer. To simplify the programming task, the "C" programming language was chosen to replace assembler completely.

A new and flexible recording format was devised and implemented to accommodate the constantly changing sensor configuration. The new format allows for the addition, modification, or deletion, of data sources with little or no impact on existing acquisition and analysis software.

A central feature of this data system is the minimization of non-remote sensing bus traffic. Therefore, it is highly desirable that each micro be capable of functioning as much as possible on-card or via private peripherals. The bus is used primarily for the transfer of remote sensing data to or from the buffer queue.

At present, the AOL data system (AOLDS) is working as planned and has been successfully flown on several missions. A paper titled "A Multiprocessor Airborne Lidar Data System" was presented in February of this year at BUSCON-88. The attached drawing is a block diagram of the current AOLDS.

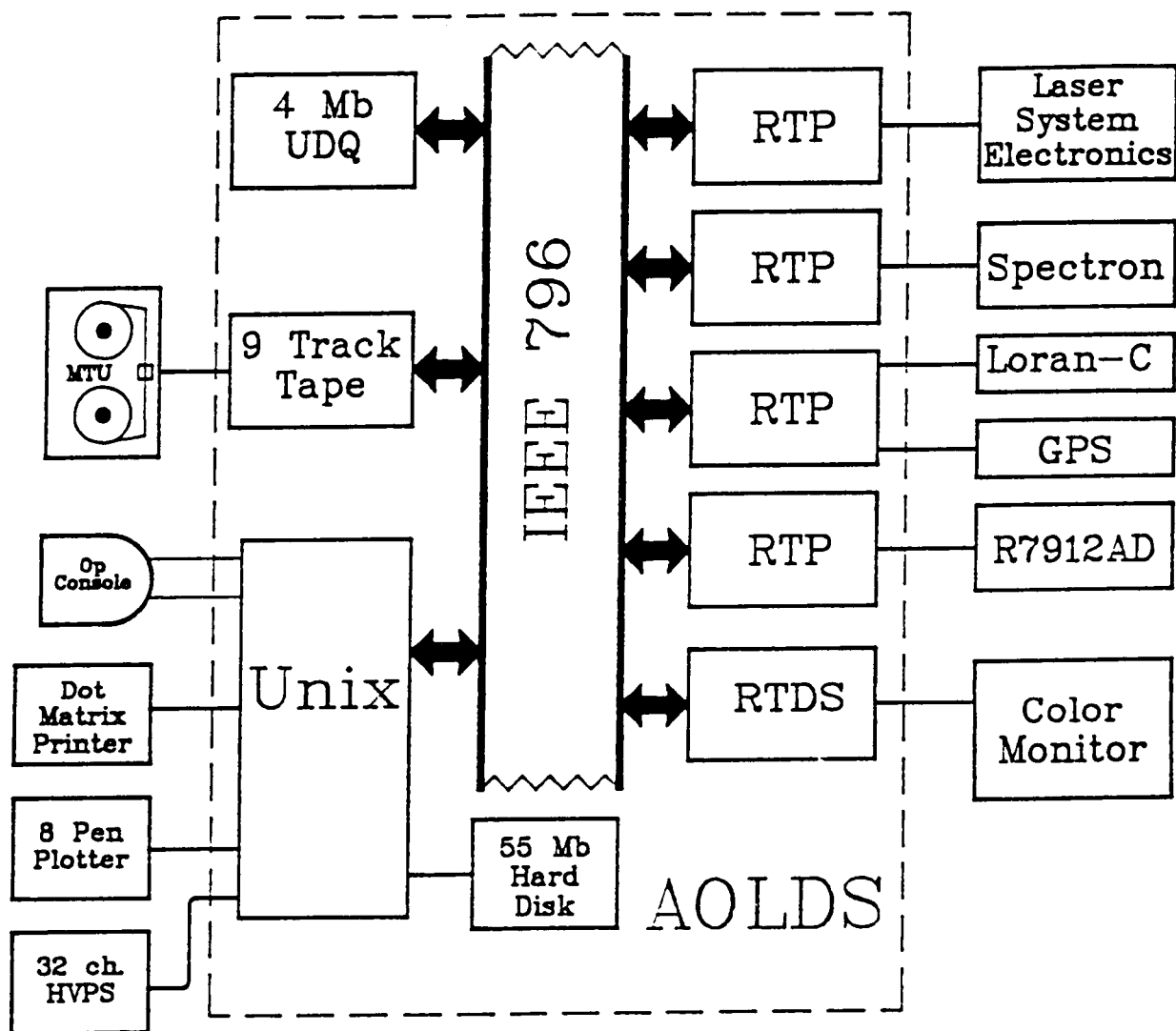


Figure 1. Data Collection System

CALIBRATION

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METEOROLOGICAL SENSOR CALIBRATION FACILITY

by

F. J. Schmidlin (672)

Radiosonde Temperature Corrections

The meteorological sensor calibration facility is designed to test and assess radiosonde measurement quality through actual flights in the atmosphere. United States radiosonde temperature measurements are deficient in that they require correction for errors introduced by long- and short-wave radiation. This situation has existed since the later 1950's when the present radiosonde design was introduced. The effect of not applying corrections results in a large bias between daytime and nighttime measurements. This day/night bias has serious implications for users of radiosonde data, of which NASA is one. Examples are: 1) ground truth (satellites such as SAGE, NIMBUS, SME, TIROS N/NOAA-series, etc., lidars, and ST-type radars); 2) temperature retrieval from satellite remote measurements (operational NOAA-series satellite retrievals depend on a regression scheme that uses the world-wide radiosonde temperature; a physical retrieval scheme is planned); 3) climatological studies and other upper-air research, especially model development; and 4) initialization data to tie-on to other measurements systems (e.g., rocketsondes). Adjustments to the temperatures and geopotentials were derived for use by analyses centers to compensate for the bias. However, these adjustments only are made to daytime measurements making them equivalent to nighttime and are not "true" corrections. The

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day/night difference at 100 hPa is estimated to be ~ 47 meters representing a temperature bias of $\sim 0.7^{\circ}\text{C}$.

The derivation of corrections for the US radiosonde is quite important. Determination of corrections depends on solving the heat-transfer equation of the thermistor using laboratory measurements of the emissivity and absorptivity of the thermistor coating. Because of the presence of other unknowns in the equation (e.g., the long-wave and incident radiant short-wave powers), simultaneous solutions of three equations is desirable using a like number of thermistors. Ninety successful flights have been made at solar elevation angles up to 80 degrees. From these measurements, a family of temperature correction curves versus solar angle as a function of pressure were derived. While the daytime correction reaches about 0.8°C , a decrease in the magnitude of the daytime correction is observed at levels above 20 hPa. Other investigators have indicated larger daylight errors at these altitudes (mostly theoretical). Although, the solar heating of the thermistor increases with decreasing density (increasing altitude), it turns out that the emissivity from the sensor is large; the long-wave emission cools the thermistor at a rapid rate, thus decreasing the daytime correction above 20 hPa.

The United States radiosonde observations from the World Meteorological Organization International Radiosonde Intercomparison were used as the data base to test whether the day/night height bias can be removed. Twenty-five noontime and

26 nighttime observations were used. Corrected temperatures were used to calculate new geopotentials. Day/night bias in the geopotentials decreased significantly when corrections were introduced.

The National Weather Service's National Meteorological Center and the European Centre for Medium-Range Weather Forecasts have offered to test the corrections in their analyses and models, respectively. We are in the process of rechecking our data prior to releasing the corrections for testing. A few papers have already been presented, and formal papers are in preparation for submission to the American Meteorological Society Bulletin. Because of the small sample, another 100 modified instruments have been procured and are to be flown this year.

Relative Humidity Sensor Lag

Some testing of thermal lag attendant with the standard carbon hygristor has taken place. Two radiosondes with small bead thermistors imbedded in the hygristor have been flown. Detailed analysis has not been accomplished; however, cursory examination of the data showed that the hygristor is at a higher temperature than the external thermistor indicates. Normal reduction procedure is to use the external temperature to reduce relative humidity for the measurements and also to calculate mixing ratio and dew point. Temperature differences of 8 to 10 degrees Celsius at 500 hPa were indicated. A further look into the seriousness of this problem is planned.

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NASA Aircraft-Satellite Instrument Calibration Project

by

B. W. Guenther (673)

D-2

Ground-based prelaunch calibration of satellite instruments usually is not adequate to provide an accurate characterization of the in-orbit performance of a satellite instrument. This is because the ground calibrations may not simulate the in-orbit environment observations of the satellite sensor, or because the sensor characteristics have changed during launch and in-orbit operations. One technique to obtain a meaningful in-orbit calibration of satellite sensors is to acquire simultaneous observations of an Earth scene with the satellite and a well calibrated aircraft or shuttle sensor which has similar characteristics to the satellite sensor. This is a direct in-orbit calibration technique and is usually called vicarious calibration. The experiment with the control instrument must occur above the sensible atmosphere as measured by the satellite sensor to provide a useful improvement to the calibration of the satellite sensor.

NOAA/NESDIS initiated a vicarious aircraft calibration program in the early 1980's. The instrument is used primarily to calibrate the AVHRR and VISSR instruments on the NOAA operational satellites, but has also been used to check the performance of the Coastal Zone Color Scanner (CZCS) instrument on the Nimbus 7 platform. The program has recently been transferred to the Laboratory for Oceans. The primary control instrument is a

double Ebert monochrometer with a silicon photodiode detector. It is currently set to scan from 400 to 1040 nm, and flies on the NASA U-2 and ER-2 aircraft from the Ames Research Center. The spectrometer has been returned to our laboratories for requalification and careful documentation of its configuration and performance. The instrument will be tested for calibration stability at our large aperture integrating sources, and checked for operational integrity in our environmental vacuum chamber. An engineering flight is scheduled for the Summer on the Wallops Flight Facility T-39 aircraft, and operational vicarious missions will be reestablished in the Fall from Ames.

The project is assigned to Goddard under the terms of a joint NASA-NOAA Memorandum of Understanding, and NOAA personnel continue to provide the primary interface for the project with the Ames flight mission staff. The NASA portion of the mission is funded through the NASA Headquarters Flight Projects Branch.

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FLIGHT CALIBRATION SOURCE DEVELOPMENT

by

S. Glicker (673)

An important element in monitoring the sensitivity of flight instrumentation throughout a flight is a reliable reference. Tungsten filament quartz halogen and deuterium uv sources have been tested for this purpose. All three types were obtained from available commercial supplies and were tested against various mission requirements, particularly long-term stability characteristics. Stability tests were made before and after thermal vacuum and vibration tests.

A lamp assembly for SSBUV flight has been completed. Design of an integrating sphere to house the lamps and optics to transfer light from the flight sources into the Shuttle-borne SBUV (SSBUV) field of view for in-flight stability checks has been completed. The transfer optic element is a mirror 4-inches in diameter with a 5-inch radius of curvature. The mirror is mounted on the Get-Away-Special (GAS) canister lid, and the integrating sphere is mounted on the SSBUV instrument top deck. Our current analysis indicates that a 45-watt tungsten filament lamp mounted in the integrating sphere will provide as much energy for instrument stability checks as a 100 watt calibrated tungsten filament standard lamp in the laboratory provides for system calibrations.

The lamp assembly was tested in-house, and included a ray trace analysis. The multiple lamp sources will provide redundant and duplicative measurement to check system degradation.

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RADIANCE STANDARDS

by

D. L. Lester (673)

Our Office maintains and operates two radiometric calibration sources that are utilized by various groups within Code 600. One source is a 6-foot diameter sphere and the other a 4-foot diameter hemisphere. Both are internally coated with multiple layers of barium sulfate and house an array of 12 tungsten filament-quartz iodine lamps that provide a uniform diffuse target of radiance traceable to NBS. The lamps are baffled and arranged so that they are not part of the scene during calibrations. Both systems have a 10-inch viewing aperture. The hemisphere is somewhat more versatile in that the aperture can be changed and the system is movable so calibrations can be done at other sites.

Together, these systems have supported numerous GSFC projects and missions during this review period. They include the First International Satellite Land Surface Climatology Project (ISLSCP) Field Experiment (FIFE), French SPOT-2 satellite, Acid Rain Studies, Forest Canopy Studies, the First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE), the University of Maryland MECCAS project, the Sudan Rangeland Project, the Satellite Precipitation and Cloud Experiment Microburst and Severe Thunderstorms program (SPACE/MIST), and the Arctic Airborne Science Expedition.

User codes and instruments calibrated are shown below;

Goddard Code

Instrument

613	Barnes Transmissometer
617	Multispectral Cloud Radiometer (MCR) Modular Multispectral Radiometer (MMR)
623	Integrated Camera and Radiometer (ICAR) Portable Field Spectrometer (SE590) Bidirectional Reflectance Field Instrument (BRFI) Exotech Radiometer, Field Polarimeter, MMR
673	SPOT-2 in Toulouse, France Thematic Mapper Simulator at Ames
674	Cloud Absorption Radiometer (CAR) Advance Scanning Array Spectrometer (ASAS) Biometer II, MCR, Field Polarimeter Ocean Data Acquisition System (ODAS)

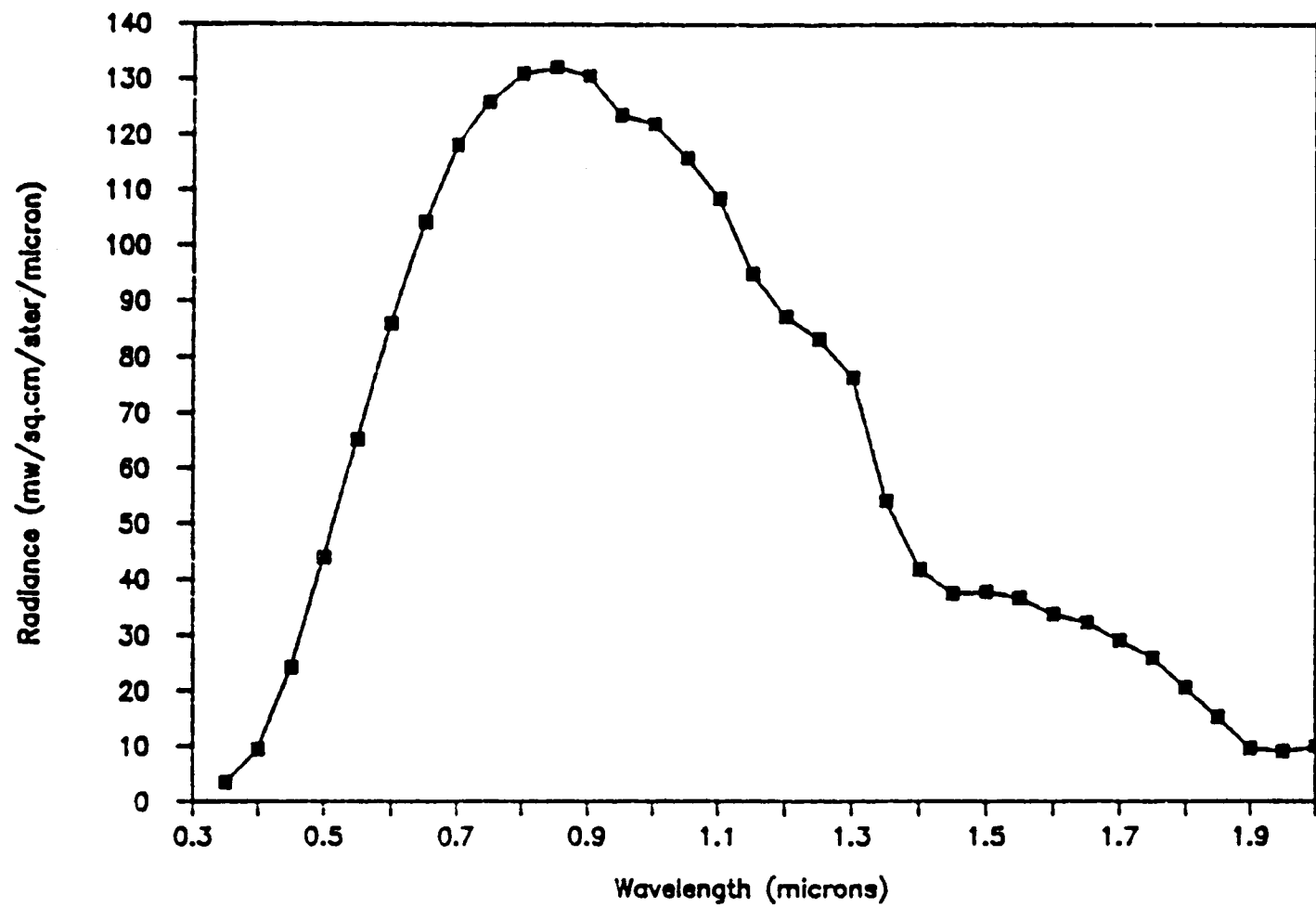


Figure 1. GSFC Six Foot Sphere Data
Ave.Data/JM/DL/2/88

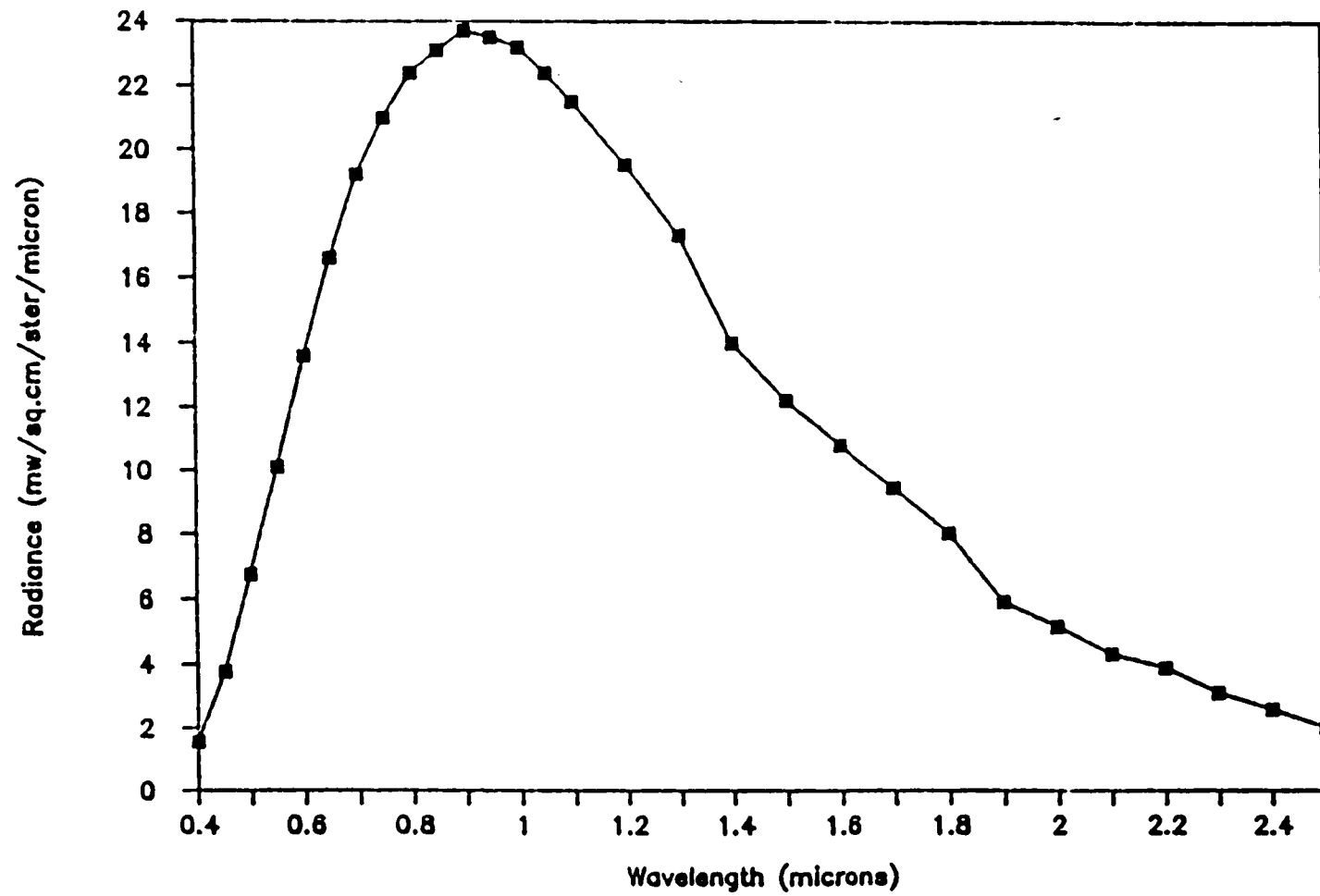


Figure 2. GSFC Hemisphere Data
GSFC/DL/1/8w12/86

ENVIRONMENTAL CALIBRATION CHAMBER OPERATIONS

by

D. L. Lester (673)

The Office has thermal vacuum capabilities that are provided for use by Code 600 personnel in the development, calibration, and functional operation checks of flight sensors, sources, and laboratory and field instruments. Two systems are available. The first is a 46 cm diameter diffusion-pumped vacuum chamber of the bell jar variety. It has an internal thermal shroud, LN2 cold trap, two viewing ports, and various electrical and fluid feedthroughs. The other, also an oil diffusion-pumped system, consists of a 1.8 meter diameter by 2.5 meter long stainless steel vacuum tank, associated pumping and control equipment, a liquid nitrogen storage and transfer system and internal IR/visible calibration sources. This is a two story system with the chamber located on one floor and the pumping/cryogenic systems located on the floor below.

ACTIVITY SCHEDULE

<u>CODE</u>	<u>INSTRUMENT</u>	<u>DESCRIPTION</u>	<u>DATE</u>
673	SSBUV Flight Candidate Lamps	Environmental temperature characterization.	3/86
617	Cloud LIDAR	Functional test at flight pressure.	4/86
674	Multispectral Cloud Radiometer (MCR)	Pre-flight calibration of IR channel.	5/86
616	SSBUV Horizon Sensor	Instrument development	5/86
673	SSBUV Flight Calibration Lamps	Thermal soak in vacuum.	7/86 & 8/86

<u>CODE</u>	<u>INSTRUMENT</u>	<u>DESCRIPTION</u>	<u>DATE</u>
674	MCR	Pre-flight IR calibration	9/86
674	Thermalert II Sensor	IR Calibration	11/86
674	MCR	Post-flight IR calibration	12/86
671	PRT 5 (2)	Pre- and Post-flight temp. characterization	5/87 & 6/87
623	Telatep Tehmometer Gun	IR calibration	5/87
674	MCR	Pre- and Post-flight IR calibration	6/87 & 9/87

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CALIBRATION SOURCE MAINTENANCE,
CHARACTERIZATION AND DEVELOPMENT

by

J. T. McLean (673)

The Standards and Calibration Office maintains visible and near infrared calibration sources for the use of various GSFC organizations instrument calibration needs and related field activities. These are large aperture spherical and hemispherical integrating sources designed to provide a spatially uniform absolute spectral radiance with a well-defined angular uniformity characteristic.

A brief physical description of both the hemisphere and the 6-foot sphere is included in section on Radiance Standards. In essence, the calibration and characterization efforts involve monitoring and documenting the stability and the absolute radiance of these calibration sources. These sources are recalibrated by Code 673 personnel on a regular basis to both document any changes that might occur in the output of the sources and to provide the most up-to-date calibration data for the source users. Our efforts included comparing our calibration numbers with those of a commercial calibration laboratory that we engage to do independent calibrations. However, the most recent calibrations done by the independent laboratory and those done by GSFC personnel show a rather large discrepancy (10 to 15 percent). Efforts are underway to resolve these differences.

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INTEGRATING SPHERE AND HEMISPHERE CALIBRATION UPDATE

by

J. T. McLean (673)

BACKGROUND:

This background information relates to the conclusions reached about the GSFC/Optronics calibrations for the 6-foot sphere. The history of these calibrations date back to the year 1978 when Optronics first calibrated this sphere. The comparison of the data taken then indicated rather close agreement between the measurements taken by GSFC and Optronics Labs. This trend continued in 1979 and in 1982. The sphere was refurbished in terms of repainting and changing the lamps in the Spring of 1985. As a result of the refurbishing, the output radiance of the sphere nearly doubled going from about 80 to 140 in relative numbers as reflected in data taken by both Optronics and GSFC.

This high output seems to have an effect on the values we measure. A comparison of data taken by Optronics and GSFC show differences of 12 to 15 percent rather than the 2 to 3 percent that we had seen in past measurements. The reasons for the differences are not clear. While Optronics has changed their calibration equipment and methods somewhat, the changes are the types that should tend to improve the measurement. Although the GSFC measurement procedure has not changed, the personnel performing the measurement has changed, and the results seem to be reasonably consistent with previous measurements.

RECENT DEVELOPMENTS:

Both the hemispherical and the spherical integrating sources were remeasured in February 1988 by two experimenters and the results show a decrease in the output of the sphere. But the discrepancy between GSFC data and Optronics Data remains. The decrease in the output can be accounted for by a correction in the current value of power supplies Number 2 and Number 3. The supplies were running about 1.75% high. Minor differences were noted in the short wavelength end of the hemisphere.

The data represents a composite of the average of all the data taken by the different detectors, namely, silicon, germanium, lead sulfide; different spectrometers, and different operators. The estimated uncertainty in the precision of our measurement is $\pm 3\%$. However, the uncertainty in absolute accuracy is estimated to be somewhat higher, probably 5% to 10%.

Efforts to resolve the discrepancy between GSFC and Optronics Labs as well as improve our ability to make more accurate and precise measurements are underway. Arrangements are being made for a meeting between GSFC personnel and Optronics Laboratory people to make some comparison measurements and discuss the measurement techniques involved. Design of new fixtures to position and align the calibration test equipment to improve precision has been initiated. Updating the measurement equipment to make it more computer compatible is being considered.

Our recommendation is that these calibration constants be used as GSFC's best estimates within the uncertainties noted above. The

values given for the hemisphere are considered as being more reliable than those of the 6-foot sphere since the precision of measurement for the hemisphere is somewhat higher than that for the sphere. However, the uncertainties in the absolute values of each device are probably comparable.

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